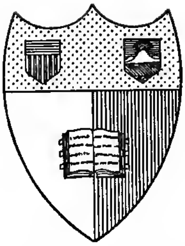

Cornell University Library
Ithaca, New York

FROM

Supt. of Documents

Cornell University Library
UG448 .W53

Notes on seacoast fortification construc

3 1924 030 766 046
olin

Cornell University Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

http://www.archive.org/details/cu31924030766046

NUMBER 61
OCCASIONAL PAPERS
ENGINEER SCHOOL
UNITED STATES ARMY

NOTES ON SEACOAST FORTIFICATION CONSTRUCTION

By

COL. EBEN EVELETH WINSLOW
CORPS OF ENGINEERS, U. S. ARMY

PREPARED UNDER THE DIRECTION OF THE CHIEF
OF ENGINEERS, U. S. ARMY, FOR USE
AT THE ENGINEER SCHOOL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1920

CONTENTS.

Page.
Preface 5
Chapter I. Historical 7
Chapter II. Administration 25
Chapter III. Armor and armament 33
Chapter IV. Material used in emplacement construction 49
Chapter V. Ammunition supply, storage, and service 71
Chapter VI. Batteries and emplacements, general design 101
Chapter VII. Emplacement details 159
Chapter VIII. Mortar batteries 199
Chapter IX. Dryness, heating, and ventilation 225
Chapter X. Blast effects 261
Chapter XI. Uses of electricity in fortifications 269
Chapter XII. Fire control 303
Chapter XIII. Night illumination of battlefields 369
Chapter XIV. Submarine mining 407
Chapter XV. Summary 431

LIST OF PLATES.

PLATE I. Some of the details of ammunition service apparatus.
PLATE II. Some of the details of ammunition service apparatus.
PLATE III. Emplacements for two 3-inch guns (balanced pillar mounts) 1898 type. Drawing based on Mimeograph No. 30.
PLATE IV. Emplacements for two 3-inch guns (pedestal mounts) 1902 type. Drawing based on fifth supplement to Mimeograph No. 30.
PLATE V. Emplacements for two 3-inch guns (pedestal mounts) 1903 type. Drawing based on sixth supplement to Mimeograph No. 30.
PLATE VI. Emplacements for two 5-inch guns (balanced pillar mounts) 1897 type. Drawing based on Mimeograph No. 18.
PLATE VII. Emplacements for three 5-inch guns (pedestal mounts) 1899 type. Drawing based on Mimeograph No. 33.
PLATE VIII. Emplacements for two 6-inch guns (pedestal mounts) 1900 type. Drawing based on Mimeograph No. 40.
PLATE IX. Emplacements for two 6-inch guns (pedestal mounts) 1901 type. Drawing based on plans of Battery Montgomery.
PLATE X. Emplacements for two 6-inch guns (pedestal mounts) 1902 type. Drawing based on second supplement to Mimeograph No. 40.
PLATE XI. Emplacements for two 6-inch guns (disappearing carriages) 1903 type. Drawing based on Mimeograph No. 59.
PLATE XII. Emplacements for two 6-inch guns (disappearing carriages) 1912 type. Drawing based on plans of batteries designed for Panama Canal.
PLATE XIII. Emplacements for two 10-inch guns (disappearing carriages) 1894 type. Drawing based on the design of a battery built at Fort Monroe.
PLATE XIV. Emplacements for two 10-inch guns (disappearing carriages) 1896 type. Drawing based on Mimeograph No. 4.

PLATE XV. Emplacements for two 10-inch guns (disappearing carriages) 1898 type. Drawing based on Mimeograph No. 22.

PLATE XVI. Emplacements for three 10-inch guns (disappearing carriages) 1900 type. Drawing based on Mimeograph No. 36.

PLATE XVII. Emplacements for two 10-inch guns (disappearing carriages) 1903 type. Drawing based on Sixth Supplement to Mimeograph No. 36.

PLATE XVIII. Emplacements for two 12-inch guns (disappearing carriages) 1896 type. Drawing based on Mimeograph No. 4.

PLATE XIX. Emplacements for two 12-inch guns (disappearing carriages) 1898 type. Drawing based on Mimeograph No. 24.

PLATE XX. Emplacements for two 12-inch guns (disappearing carriages) 1903 type. Drawing based on Mimeograph No. 66.

PLATE XXI. Emplacements for two 12-inch guns (barbette carriages) 1915 type. Drawing based on general outline plans.

PLATE XXII. Left emplacement of a battery of two 14-inch guns (disappearing carriages) 1908 type. Drawing based on Mimeograph No. 109.

PLATE XXIII. Emplacement for one 14-inch gun (disappearing carriage) M variety of 1912 type. Drawing based on a battery actually constructed.

PLATE XXIV. Emplacement for one 14-inch gun (disappearing carriage) S variety of 1912 type. Drawing based on a battery actually constructed.

PLATE XXV. Emplacements for two 14-inch guns (disappearing carriages) W variety of 1912 type. Drawing based on a battery actually constructed.

PLATE XXVI. Emplacements for two 14-inch guns (disappearing carriages) L variety of 1912 type. Drawing based on a battery actually constructed.

PLATE XXVII. Batteries for sixteen 12-inch mortars. 1892 and 1894 types. Drawings based on batteries actually constructed.

PLATE XXVIII. Batteries for eight 12-inch mortars. 1898 and 1906 types. Drawings based on Mimeograph No. 27 and its first supplement.

PLATE XXIX. Battery for eight 12-inch mortars. 1912 type. Drawings based on general plans.

PREFACE.

In the fall of 1906 the author of these notes was relieved from duty in charge of the Norfolk engineering district, and was sent to the Engineer School at Washington Barracks as director of military engineering. The Norfolk district, from which he came, had, during his tenure of the district, been an exceedingly active one as far as fortification construction was concerned, and had been the principal site of the joint Army and Navy maneuvers in 1905. Furthermore, during the years 1903 to 1906 a large amount of experimental Coast Artillery work had been in progress at Fort Monroe.

Immediately after arrival at Washington Barracks he began to prepare, in connection with the course in military engineering, a series of lectures on the details of seacoast defense, which were delivered during the winter of 1906 and 1907. During the following summer these lectures were revised, almost to the extent of being practically rewritten, and as thus revised were used during the winter of 1907 and 1908, being issued at this time not as lectures but in typewritten form, each student officer being furnished with his own individual copy.

These lectures were not intended to be complete in themselves, but were intended to be studied in connection with Engineering Department mimeographs and with certain engineering drawings and photographs, all of which were placed in the study rooms for use of the student officers. To these other papers and drawings frequent reference was made in the lectures. In addition to the lectures, mimeographs, drawings, and photographs there was prescribed a "course of reading," consisting of certain stated pages in certain publications, copies of which were placed in the study rooms for the aid of the student officers.

During the spring and summer of 1908 the lectures were again subject to revision and as thus revised were published in the early part of 1909 as "Occasional Papers No. 35, Engineer School, United States Army."

Since the publication of these papers the author has had practically continuous experience in fortification matters, having designed and constructed most of the fortifications of the Hawaiian Islands and having designed all the fortifications constructed up to this time in the Panama Canal Zone, and having been for four years in charge of the fortification desk in the office of the Chief of Engineers. Before leaving this desk he has thought it well to again revise his lectures under the title "Notes on Seacoast Fortification Construction."

The original lectures were not intended as a textbook on the general subject of fortification or on the application of fortification to seacoast defense, but merely as a compilation of matter for the use and assistance of those Engineer officers whose duties require them to undertake the detailed design or construction of emplacements or other features of seacoast fortification work.

It will be noted that in connection with many of the items covered in these notes considerable historical matter is inserted. This has been done not because of any special importance attached to this matter historically, but merely because it is thought that one of the best ways to prevent mistakes in the future is to call to the attention of the designing and constructing officers the defects and mistakes of the past.

WASHINGTON, D. C., *July, 1919.*

CHAPTER I.

HISTORICAL.

Before going into a description of the detailed construction of seacoast batteries, and their accessories, it would appear to be well to give a brief historical sketch of the development of seacoast defense in the United States; for in order to thoroughly understand existing conditions in our seacoast-defense work a general knowledge of the antecedent history of the subject is necessary.

The history of seacoast fortifications in this country dates back to before the Revolutionary War, but most of the fortifications built at that time were small and of minor importance. For some 10 years after the Revolutionary War, and during the formative period of our Government, but little additional work seems to have been done.

In his annual message, submitted in December, 1793, President Washington urged upon Congress the necessity of placing our seacoast in a condition of complete defense, and a few months later in same session a committee of the House of Representatives submitted to the House a report giving an estimate for the construction of fortification at important points, and making a few recommendations as to the kind of works that should be built. Based upon this report, the first appropriation for fortification construction was made in the spring of 1794.

The Secretary of War at once issued to the constructing engineers certain general instructions as to the character of the fortifications to be built. He directed that, owing to the small size of the appropriation, the works should be comparatively inexpensive, consisting of earthen parapets revetted with timber or sod. When located at distant points the batteries should be built into a closed work or redoubt, but in general the defense on the land side was to be provided for by small blockhouses. The redoubts were to be adapted to garrisons of about 500 men each, and the blockhouses to detachments of about 50 men each. The Secretary left to the judgment of the constructing engineers the question as to whether the redoubts should have embrasures or the fire should be in barbette. He, however, regarded it as very important that a reverberatory furnace for heating cannon balls red hot be erected in each battery.

Thus was our first system of seacoast defense begun. Appropriations were small and the works which were built were of rather a minor character. A few years later, however, more extensive plans were adopted and more important permanent works were begun. Fort Constitution in Portsmouth Harbor, Fort Independence in Boston Harbor, Fort Adams at Newport, and a number of other forts date back to this period.

Work had been carried on in this way for about 12 years under appropriations totaling about $1,300,000, when in the latter part of the year 1805, our foreign relations became embarrassed, and in December of that year the President, in submitting his annual message to Congress, called attention to the damage done our ports, and to ships sheltered in them, by the enemy's privateers and by pirate vessels, and to the necessity of completing our seacoast defenses. A few months later Congress made a largely increased appropriation for fortification work. Still larger works were soon planned and begun, and when, in 1812, war broke out with England, enough work had been done to put our most important harbors in a fair state of defense, though of course during the war, numerous earthworks and other hasty defenses were added.

Taken as a whole, these defenses accomplished their purpose fairly well during the war, as is shown by the comparative freedom of the coast ports from naval raids. The only attacks made upon our regular defenses were repulsed and such landings as were made were at undefended places. Had our mobile army been efficient the enemy would have been able to accomplish little.

The real beginning of our seacoast defenses dates from about 1816; that is, shortly after the close of the war with England.

The Corps of Engineers had been established in 1802, in connection with the Military Academy, but for the next few years it consisted of but little more than the Military Academy itself. By 1815, however, the corps had grown in size and importance, and Gen. J. G. Swift, then Chief of Engineers, was directed by the Secretary of War to send various engineer officers to examine the different ports of the country, to prepare plans for defensive works, and to submit estimates of the cost of the same. In December, 1815, Gen. Swift submitted an estimate to Congress of $838,000 as the cost of the work considered immediately necessary, and in the following April Congress appropriated this hitherto unequaled sum for defensive works.

In the same year, 1816, there was appointed a permanent board of Engineer officers to prepare plans for defensive works. A distinguished French officer, Gen. Bernard, was induced to come to this country and become the senior member of the board. This was the beginning of the Board of Engineers for Fortifications, which has been in continuous existence since that time.

Immediately after the organization of this board, it proceeded to make a study of the defense of our various harbors and to prepare plans for defensive works. Among the first of the forts designed by this board was Fort Monroe, the largest inclosed work ever constructed in this country. This fort contains seven bastions, and has a wet ditch 1¾ miles in length. Its armament was to consist of over 400 guns.

From time to time this board submitted to the Secretary of War reports containing plans and estimates for special defenses, which were considered of a confidential character and were not printed, but under date of February 7; 1821, a more general report was submitted containing a general study of the subject of fortifications. In this report it is stated:

> It will be seen that most of the existing forts only defend single points, and satisfy only a few essential conditions; and that they have not been planned with a view to the defense of the frontiers, considered as one great and combined system, whose several parts should be connected, and should mutually support each other. The navy yards (excepting that of Charlestown, near Boston) have all been improperly placed; the conveniences for the erection of the necessary establishments having alone been taken into consideration, while all the other requisites for points so important, such as security of attack by sea or land, facility for receiving all kinds of building materials in time of war, as well as in time of peace, vicinity to a place of rendezvous, have been overlooked.
>
> A defensive system for the frontiers of the United States is therefore yet to be created; its bases are: First, a navy; second, fortifications; third, interior communication by land and water; and, fourth, a regular army and well-organized militia; these means must all be combined so as to form a complete system.
>
> The navy must, in the first place, be provided with proper establishments for construction and repair, harbors of rendezvous, stations, and ports of refuge. It is only by taking into view the general character, as well as the details of the whole frontier, that we can fix on the most advantageous points for these naval depots, harbors of rendezvous, stations, and ports of refuge.
>
> After determining the general and connected system of naval depots, harbors of rendezvous, stations, and ports of refuge, the commission in the next place traced the scheme of fortifications necessary to protect this system, and at the same time to guard the whole frontier against invasion. The forts projected by the commission for this purpose satisfy one or more of the following conditions:
>
> 1. To close important harbors to an enemy and secure them to the navy of the country.
> 2. To deprive an enemy of strong positions, where, protected by his naval superiority, he might fix permanent quarters in our territory, maintain himself during the war, and keep the whole frontier in perpetual alarm.
> 3. To cover our great cities against attack.
> 4. To prevent as much as possible the great avenues of interior navigation from being blockaded by a naval force, at their entrances to the ocean.
> 5. To cover the coastwise and interior navigation, and give to our Navy the means necessary for protecting this navigation.

The board then took up in detail the various ports in the country, showing why and where fortifications were necessary to each. The report then continued:

> From the general exposition which we have given, it will be seen that all the fortifications projected by the board are not of the same pressing necessity, nor of like importance; that some are required immediately and that the commencement of others

may be delayed. In classing them, we shall observe that the works of the most urgent necessity are those which are destined to prevent an enemy, in time of war, from forming a permanent establishment, or even a momentary one, on the soil of the Union; those which defend our great naval arsenals, and those which protect our chief commercial cities.

In the second grade we will place those which defend stations for our Navy, and commercial cities of secondary importance, which, either from natural or artificial defenses, existing works, etc., are not entirely without protection, and can wait until the chief and more important points are secured, at least against a first attack.

Finally, in the third class, we will range the works which will complete the defensive system in all its parts but whose construction may, without imminent danger, be deferred until the frontier has received all the successive degrees of strength which the gradual erection of the forts of the first and second class will give to it.

The board then gave consideration to the number of men necessary to garrison each fort both in peace and war, and then to the cost of the defensive works. The total estimate was about $11,000,000. The board then continued:

It is proper to add that though the expense of these works be great, that expense is never to be renewed, while with troops, on the contrary, the expense is annually repeated if not increased until the end of the war. Besides the disbursements for fortifications are works in time of peace, built slowly, and to an extent, exactly corresponding with the financial prosperity of the country. Armies, however, are most wanted, and must be paid in periods of great emergency, when the ordinary sources of revenue are dried up, and when the Treasury can only be kept supplied by resort to means the most disagreeable to and the most burdensome upon the people.

The defense of our maritime frontier by permanent fortifications, and even the expense of erecting these fortifications, will thus be real and positive economy. The points of attack being reduced to a few, instead of awaiting an attack on every point, and holding ourselves everywhere in readiness to repel it, we shall force an enemy to direct his efforts against these few points, with which we shall be well acquainted beforehand, and which we shall have disposed to withstand all his attempts. There is no doubt that such circumstances will render an enemy more backward in risking his expeditions, and that we shall not only therefore be better able to resist attack, but that we shall also be less frequently menaced with invasion.

Some prominent military writers have opposed the principle of fortifying a maritime frontier. The practice of every nation, ancient and modern, has been the same in this respect. On a land frontier a good, experienced, and numerous infantry may dispense with permanent fortifications, although they would prove excellent auxiliaries and supports when properly disposed and organized; but though disciplined troops can, rigorously speaking, without their aid, cover and protect a frontier, undisciplined troops never can. On a maritime frontier the case is totally different. Troops can not supply the place of the strong batteries which are disposed along the important places. The uncertainty of the point on which an enemy may direct his attack, the suddenness with which he may reach it, and the powerful masses which he can concentrate at a distance out of our reach and knowledge, or suddenly, and at the very moment of attack, are reasons for erecting defenses on every exposed point, which may repel his attack, or retard it until reinforcements can arrive, or the means of resistance be properly organized. By land we are acquainted with the motions of an enemy, with the movements and directions of the columns; we know the roads by which he must pass. But the ocean is a vast plain without obstacle; there his movements are performed out of our sight and knowledge, and we can receive no intelligence of his approach until he has already arrived within the range of the eye. In a word, the vulnerable points of a seacoast frontier are left to their fate, if they are not covered by permanent fortifications; and their only chance of safety must then depend upon the issue of a battle, always uncertain, even when regular and well-disciplined troops, inured to danger, have been assembled beforehand, and have made all possible preparation for the combat.

If we overlook for a moment the many points of the maritime frontier which the enemy might invade with the most serious consequences to the United States; if we suppose that there exists no object on that frontier worth the trouble and expense of a great expenditure, these fortifications will even yet be highly necessary; for we still have one great object to attain—the security of our Navy. This can not be protected without fortifications, especially in struggling with an adversary superior in numbers and jealous of a supremacy on which may ultimately depend his political importance. A navy can neither be augmented nor secured without fortifications, nor can it enjoy without them the advantages which the localities of the frontier might otherwise afford. Accidents may and must happen to it; and it is only in closed and fortified harbors that it can repair the losses and disasters of a course of war, and from them, when refitted and refreshed, recommence its operations. England, herself, notwithstanding the great naval superiority which she posseses at this moment over the rest of the world, and the excellent organization of her militia, strengthens and augments the fortifications of her frontier every day; and no nation of Europe, France excepted, possesses a stronger and more complete system of permanent defenses along its coast.

Lastly, the defensive system of our seacoast by permanent fortifications being completed, and the Union being protected against all danger of invasion from that quarter, she can direct all her resources toward her Navy. Her national quarrels will then all be decided upon the ocean, and no longer upon her own territory; her wars will all be maritime; a species of warfare in unison with the institutions of the country less costly in men and money, and which, by keeping off all aggressions from her own territory, will preserve untouched her industry, her agriculture, her financial resources, and all the other means of supporting a just and honorable war.

As for the garrisons which these forts will require in time of war, a small portion of them, equal in number to the garrisons necessary in time of peace, may be composed of regular troops; the surplus of militia practiced to the maneuvers of artillery; for the greatest part of the troops required for the defense and service of these great coast batteries should be composed of Artillery.

To this end every State might organize a certain number of battalions of militia Artillery, proportioned to the exigencies and armament of the forts upon its coast, or within the sphere of activity of its military force. These battalions should be within call of the forts so long as no invading expedition is announced, but as soon as some operations of an enemy should menace the frontier, they should throw themselves into the forts, and remain there as long as the precise point of attack should remain uncertain. This system of defense for the coast was established in France, where it succeeded very well. It appears to us to harmonize as well with the institutions and spirit of the country as with the principles of economy, which should direct and govern all the expenses of the Government.

If to our general system of permanent fortifications and naval establishments we connect a system of interior communications by land and water, adapted both to the defense and to the commercial interests of the country; if to these we add a well-constituted regular army, and perfect the organization of our militia, the Union will not only completely secure its territory, but preserve its national institutions from those violent shocks and revolutions which, in every age and in every nation, have been too often incident to a state of war.

In the present report we have taken no account of the interior and land frontiers of the Union; they have not yet been sufficiently reconnoitered to enable us to give an exact idea of the system of defensive works which they may require. All that we can say by anticipation is that, from their general topographical features, these frontiers can be covered, at a very moderate expense, by such a defensive system that no enemy will be able to invade them without exposing himself to disasters almost inevitable; and that the armies of the United States, supposing all her warlike preparations well organized beforehand, will be enabled, at the very opening of the first campaign, to carry the theater of war beyond her own territory.

A few years later the board submitted another general report upon the means and works of the defensive system which it considered was for the best interest of the United States to adopt. This report states:

> The means of defense for the seaboard of the United States, constituting a system, may be classed as follows: First, a navy; second, fortifications; third, interior communications by land and water; and fourth, a regular army and well-organized militia.
>
> The navy must be provided with suitable establishments for construction and repair, stations, harbors of rendezvous, and ports of refuge, all secured by fortifications, defended by regular troops and militia, and supplied with men and materials by the lines of intercommunication. Being the only species of offensive force compatible with our political institutions, it will then be prepared to act the great part which its early achievements have promised, and to which its high destiny will lead.
>
> Fortifications must close all important harbors against an enemy, and secure them to our military and commercial marine; second, must deprive an enemy of all strong positions, where, protected by naval superiority, he might fix permanent quarters in our territory, maintain himself during the war, and keep the whole frontier in perpetual alarm; third, must cover the great cities from attack; fourth, must prevent, as far as practicable, the great avenues of interior navigation from being blockaded at their entrance into the ocean; fifth, must cover the coastwise and interior navigation by closing the harbors and the several inlets from the sea which intersect the lines of communication, and thereby further aid the navy in protecting the navigation of the country; and, sixth, must protect the great naval establishments.

From time to time in later years similar reports were made by the Board of Engineers, but it is not considered necessary to quote from them.

Under the supervision of the Corps of Engineers and upon plans prepared by the Board of Engineers, work on our seacoast defenses was continued with fair regularity until the outbreak of the Civil War. Of course, modifications and improvements in the method of construction were made from time to time, but, taken as a whole, the works were carried out on one general system.

The locations selected for defensive works were usually in close proximity to the navigable channels, and generally where the channels were rather narrow. This brought them frequently quite close to the cities and harbors they were intended to protect. Where the channels were wide, defenses were built on both sides, and in some cases artificial islands were constructed on shoals so that defenses might be built closer to the navigable channels. A prominent example of this kind of work is Fort Wool (formerly Fort Calhoun), situated on an artificial island built by depositing riprap on a shoal at the mouth of Hampton Roads, Va.

In most cases the larger forts consisted of a closed enceinte surrounded by a ditch with a high scarp wall. On all sides from which a land attack was to be feared the ditch was finished on the outside with a revetted counterscarp, covered way, and glacis. These ditches were usually dry, although where conditions made it possible, as at Fort Monroe, a wet ditch was provided. The trace of the works was usually on the bastioned system, and a thorough system of ditch defense was always provided, sometimes by casemates in the flanks of the bastions, sometimes by counterscarp galleries, and sometimes by caponnieres. On the land fronts complicated outworks were not uncommon, and demilunes were quite numerous.

The crests of all these forts were lined with heavy guns in barbette, the heaviest being placed on the water fronts. In some localities the fire brought to bear on the water was increased by water batteries constructed outside the ditches. At other places everything exterior to the ditch was omitted on the sea front, the curtains of the bastions on these fronts being armed with casemated guns.

In some extremely important localities, tall seacoast batteries were constructed, consisting of several tiers of masonry casemates surmounted by a barbette tier at the top. The battery of this character which was most nearly completed was at Fort Wadsworth, Staten Island, but other batteries of the character were begun at other places, such as Willets Point (now Fort Totten), Long Island Sound, N. Y., and at Fort Wool, Va.

As a general rule, in the North and East, where stone was obtainable, the forts were built of granite, but on the south Atlantic and Gulf coasts, where stone was not obtainable, brick was the building material commonly used.

Shortly before the Civil War there was introduced into the casemates of the forts what was called the "Totten embrasure," named after its inventor, Gen. Totten, afterwards Chief of Engineers. This consisted of a pair of heavy wrought-iron shutters hinged on either side of the opening. When the gun was ready to fire, the shutters were pushed by hand nearly all the way open; when the gun was fired the blast of the discharge opened the shutters all the way and they then bounded back shut, and were caught and held by a spring latch and thus concealed and protected the detachment while reloading the gun.

At the beginning of the Civil War the fortifications in the Southern States fell at once into hands of the Confederates and were prepared for defense by their Engineer officers, many of whom had previously served in the United States Corps of Engineers. The Confederates at once hastily finished all incomplete works and added greatly to the strength of the completed ones by throwing up earthwork batteries. That such a system of seacoast defenses was quite efficient was demonstrated during the Civil War. In spite of the size and strength of our Navy, the naval attacks on the forts were repulsed in almost every case, and when the seacoast forts were captured, it was usually only by the aid of land forces and frequently after regular sieges.

History Since the Civil War.

The period of the Civil War and a few years preceding and following it was one of rapid development in the manufacture of guns and armor and in naval architecture. The introduction of steam power for propelling ships removed them from their dependence on winds and tides and gave them the power of approaching forts and of retreating at will. The use of wrought iron as side armor, by decreasing the vulnerability of ships, increased their chances in conflict with shore batteries. The power of naval guns had been increased so that they were able to successfully attack the masonry walls of fortifications. From these changes there resulted, therefore, a change in the art of seacoast defense.

In 1865 the Board of Engineers was directed by the Chief of Engineers to consider what modifications in seacoast defense the experience of our Civil War and contemporaneous developments abroad had rendered desirable in our seacoast defense. The board was in addition directed to report specifically upon the possibility of substituting wrought-iron armor for masonry work and upon the advisability of mounting our guns, so that when not in use they might slide down behind the parapet.

The board gave these subjects careful consideration and, after considerable deliberation, submitted a long report, their principal recommendations being to the effect that our seacoast defenses should preferably consist of powerful batteries of guns of the largest caliber, that the disappearing gun carriage should be introduced, that mortar batteries should thereafter play an important part in seacoast defense for firing against the decks of vessels (their weakest portion), that torpedoes and physical obstruction of channels should be used where possible, that it was no longer advisable to use granite casemate batteries, and that armor as a substitute for granite fronts or for use in connection with granite in casement fronts had not as yet proved satisfactory.

From the close of the war up to 1875 small appropriations were made annually for fortification construction, and with the money thus provided considerable work was done. Much repair work and rebuilding was necessary, especially along the south Atlantic and Gulf coasts. At many places new earthen batteries were constructed, generally exterior to the enceinte, the guns being mounted in barbette. The disappearing carriages were not generally introduced, though experiments had shown the "King carriage," invented by Maj. W. R. King, Corps of Engineers, to be serviceable.

The barbette guns were usually grouped in pairs and, to prevent enfilade, the pairs were separated by thick traverses of earth extending high above the crest of the parapet; service magazines were usually built in these traverses. The guns employed at this time were the 10 and 15-inch muzzle-loading smoothbores; the 10-inch guns being subsequently altered into 8-inch rifles, and the 15-inch guns into 11-inch rifles.

After 1875 Congress ceased for several years to make further appropriations for the construction of seacoast batteries, contenting itself with small and utterly inadequate appropriations for the preservation and repair of existing fortifications. This condition existed for nearly 15 years, and it was not until August, 1890, that Congress began again to appropriate for battery construction.

In thus neglecting our seacoast defenses, Congress was acting directly contrary to the advice of the Corps of Engineers, as the Chief of Engineers never failed, in his annual report, to submit a strong plea for renewal of the work. On pages 4 to 18 of the Annual Report of the Chief of Engineers for 1880 there will be found an especially strong plea for resuming work on the defenses, and in the report for 1881, pages 399 to 415, there is a letter to the Chief of Engineers from Col. Gilmore, of the corps, which is worth study.

On March 3, 1885, Congress passed an act authorizing the formation of a board to be composed of Army and Navy officers and of civilians to examine into and report upon the subject of seacoast defenses. This board was shortly afterwards appointed by the President, and became known as the "Endicott Board," from its senior member, Secretary of War Endicott. This board, dividing itself into committees, made a long and careful study of the different features of seacoast defense, and, in 1886, submitted its report.

The report of the board is quite lengthy and takes up first the general subject of where fortifications should be established. It then selects the places which should be fortified, gives in detail the fortifications which should be provided in these places, and mentions the order in which the work should be done. It also makes a very careful summation of the number and caliber of guns which should be emplaced with the cost thereof, and of all other elements of the defense.

In 1890, Congress decided to act upon the recommendation of the Endicott Board, and in August of that year made an appropriation for the construction of seacoast defenses, the first for 16 years. The amount of this first appropriation was $1,200,000. Other appropriations followed, the annual average being about a half million dollars until 1896. In this and the following few years, the amounts were still larger.

The first appropriation which was made by Congress was directed to be distributed between Boston, New York, and San Francisco, and the next year Hampton Roads was added to the list. In the later appropriation acts no restrictions as to the distribution of the appropriation were made.

From the first appropriation allotments were made for barbette batteries at San Francisco, for disappearing 8-inch guns in New York Harbor, for a 12-inch gun-lift battery at Sandy Hook, and for mortar batteries at Sandy Hook and at the Presidio, San Francisco. Work on these and other batteries was pushed rapidly, though progress on the disappearing emplacements was delayed until the Ordnance Department could develop a suitable type of disappearing carriage.

The estimates that were submitted by the Endicott Board were necessarily based upon the gun carriages, types of emplacements, etc., known at the time (1885 and 1886), but before actual work was begun many improvements and developments had been made. However, the Endicott Board had made liberal allowance for such improvements and contingencies, and these estimates were so well made that they remained, for about 20 years, the official basis upon which annual requests for funds were made to Congress. That is, in each annual report the Chief of Engineers would make a statement of the total amount which had been appropriated, the number of guns which had been mounted, and number of emplacements which had been provided for. This was compared with the figures of the Endicott Board, and the differences were stated as being the number of guns still to be mounted, the number of emplacements still to be built, the amount of money still to be appropriated.

In the meantime, however, there had been a rapid development, not only in the manufacture of ordnance and in the construction of emplacements, but in auxiliaries, such as fire control, searchlight illumination, etc.

Accordingly, the President, under date of January 31, 1905, organized what is officially known as the National Coast Defense Board and what is informally known as the Taft Board, Secretary of War Taft (afterwards President) having been the presiding officer of the board. After due consideration, this board submitted a report which is now the basis of estimates.

The report of the Taft Board is much shorter than that of the Endicott Board report and should be read by all students of fortification history. It first reviews briefly the Endicott Board report and the conditions which required the formation of that board. It suggests certain new harbors as being worthy of fortifications—the entrance to Chesapeake Bay, the eastern entrance to Long Island Sound, our insular possessions, and the entrances to the Panama

Canal. It suggests some slight modification in the character of guns to be mounted, and especially the introduction of the 14-inch gun as the standard seacoast defense gun in preference to the 12-inch, which had theretofore been considered the largest gun. The report also laid great stress upon the importance of searchlights and adequate fire-control systems.

Finally, the board made a summary of the cost of all the work recommended by it and recommended that this cost be taken as the new basis of estimates and appropriations.

As had been the case with the Endicott Board report, the Taft Board report, after its submission to the Secretary of War, thence to the President, and thence to Congress, was assumed as the standard upon which seacoast defense should be based. The various suggestions of this report as to searchlight and fire-control installation, and as to other details, were all carried into effect by the War Department.

Unfortunately, however, the principal use made of this report seems to have been as a basis of estimates. Thus, the War Department in submitting its annual report to Congress stated each year that the Endicott Board report, as modified by the Taft Board report, recommended a certain number of guns of each caliber, that there had been emplaced or provided so many guns of that character, and that therefore there remained so many to be emplaced and so many to be provided; that the board estimated the total cost of emplacement construction as so much; that so much had been appropriated by Congress, and that the balance, therefore, was the amount still to be appropriated. Similarly with regard to fire control and searchlights.

In thus making the figures compiled by the Taft Board an unchangeable basis of estimates, the War Department was but continuing the policy which had been customary, at least since the acceptance of the report of the Endicott Board. Moreover, the department was but carrying out the suggestions of the Bernard Board, for, as may be noted in one of the quotations in the early part of this chapter, the Bernard Board in advocating the constructions of fortifications around our frontiers used as an argument the statement that the expense of a fortification construction once incurred would never have to be renewed, while, on the other hand, the cost of maintaining a mobile army was one that must be repeated annually.

A century ago, when, in spite of the impetus of the Napoleonic wars, the application to military art of mechanical inventions and developments was proceeding but slowly, and when the portions of fortifications in the immediate vicinity of the gun emplacements were constructed of earth which could be easily changed at will, it might have been considered fairly true that fortifications once constructed could be expected to remain fairly efficient for quite a number of years.

This, however, is no longer true. Inventions are being made by the thousands, and the adaptation to military affairs of recent inventions and discoveries is being made by leaps and bounds. An emplacement, at least, in the immediate vicinity of the guns consists usually of concrete, which once set is permanent and which costs several times as much to remove as to put in place.

That it is dangerous to rely upon a fortification remaining fairly up to date, even for a period of but two or three decades, is shown by the disastrous failure of the Belgian fortifications in the summer of 1914 to stop the advance of the German army.

The fortifications of the Belgian cities had been constructed only about a quarter of a century. They had been designed by the foremost fortification engineer of the day. They had been built to withstand the fire of guns larger than any which it was then thought possible to transport with a field army, and the armament consisted of even heavier guns. However, before these fortifications were three decades old they were confronted by the advancing German Army bringing forward guns of a size never before used with a field army and theretofore considered available for fortress use only. These heavy guns outclassed the Belgian guns and fired projectiles which the defenses were not intended to withstand. As a result, before many days had passed the Belgian fortifications had been battered out of existence.

Making a text of this occurrence, the Chief of Engineers in November, 1914, submitted to the Chief of Staff a memorandum on the subject of "The Obsolescence of Seacoast Emplacements," which reads in part as follows:

> In connection with the easy capture by the Germans of Belgian fortresses and the inability to withstand modern ordnance shown by fortifications built more than 20 years ago and designed to withstand guns of that time, the Chief of Engineers considers it advisable to bring certain facts connected with our existing seacoast fortifications to the attention of the Chief of Staff.
>
> On the eastern shore of the United States—that is, on the Atlantic and Gulf coasts—there have been emplaced since 1890 two hundred and seventy-two 12-inch mortars and eighty-one 12-inch rifles, 64 of the latter being mounted on disappearing carriages and 17 on barbette carriages. These guns constitute the primary armament, and in this connection no attention will be paid to the guns of smaller caliber.
>
> Of these emplacements for the larger guns, 248 of the mortar emplacements and 60 of the 12-inch emplacements were designed and begun prior to the Spanish War. The last mortar emplacements were designed and begun in 1900–1901, and the latest type 12-inch emplacements, namely, Batteries Parrott, at Fort Monroe, and Wheaton, on Narragansett Bay, were planned and begun about 1903 and were practically ready for use in 1905.
>
> Of the ships of the United States Navy now carried as first-line battleships, the very oldest, the *Michigan* and the *South Carolina*, were designed and begun in 1905, or about the time the latest of our eastern seacoast batteries were completed.

Judged by the naval standard, therefore, we have not on the Atlantic coast a single "first-line" emplacement.

In our Pacific defenses conditions are in general the same as on the Atlantic coast. Of the 104 mortar emplacements and twenty-four 12-inch rifle emplacements which have been built, only two, the 12-inch emplacements at Fort Worden, may be considered as fairly modern, having been designed in 1908. However, work is about to be begun on new defenses at San Diego and Los Angeles.

For many years the Navy Department has been educating public opinion and the ideas of Congressmen to the fact that the life of a battleship is limited; that after a comparatively small number of years it must be relegated to what is called the second line; after a few years more it must go in reserve for emergency use only, and, when 20 or 25 years of age, is to be classed as obsolete and can be considered as fitted only to be broken up, or to be used, like the *San Marcos* (formerly the battleship *Texas*), as a target for its more modern sisters.

With vessels and floating craft there are, of course, other things to be considered besides armor and armament, such as the hull, the propelling machinery, and the destructible nature of the very material used in construction; but the reasons for relegating ships to the second line or to the reserve are not usually defects in the hull or propelling machinery, but rather the obsolescence of the armament, armor, or other matters directly connected with offense or defense.

In connection with this obsolescence of battleships the Navy Department, year by year, presents statements to Congress to the effect that in order to keep the Navy efficient and up to date a certain number of battleships must be laid down each year, this number usually being stated at four.

Unfortunately, the War Department has not seen fit to adopt a similar policy, but has permitted it to be understood that a seacoast battery, once constructed, remains practically indefinitely up to date. For instance, from 1890 until about the time of the formation of the Taft Board in 1905, the department each year in its annual report would state that, based upon the report of the Endicott Board and the revision of certain projects up to date, it was estimated that a certain number of emplacements of each caliber were necessary to complete the defenses of the country, that a certain number had been constructed, and that the difference represented the number to be built.

In the report of the Taft Board in 1905 no attempt was made to bring the subject of seacoast fortifications up to date, though new estimates were made of the number of guns still to be emplaced and of the cost of doing this work. However, since the report of the board, the same policy as to estimates mentioned above has been essentially followed, and nowhere in the report of the Taft Board nor in the annual reports of the department is attention called to the fact that our emplacements rapidly get out of date, and to keep our coast defenses efficient fortification construction must go on practically continually.

As a partial step toward keeping the batteries up to date estimates were submitted by the Taft Board for modernizing older batteries, and, under this head, approximately $1,090,000 has been provided by Congress. With the funds thus provided much work has been done; in improving projectile hoists and widening loading platforms so as to provide easier and more efficient ammunition service and thereby insure greater rapidity in fire; in the installation of ventilating apparatus and the prevention of dampness in our magazines; and in the introduction of other modern appliances. Such modernizing, however, is really analogous to the repairs and overhauling which are periodically done on our battleships and in spite of which periodical overhauling our battleships still grow out of date. Consequently, it can never be expected that our emplacements can be kept up to date by merely tinkering with them.

Our seacoast batteries when built were designed to withstand guns of the day, and a fair factor of safety was provided to allow for the future advancement in ordnance. The time elapsed, however, since they were designed has been so great and the advances in ordnance have been so rapid that many of our older magazines are not adequately protected against modern naval rifles. In may cases, of course, the additional necessary protection can be added by excavating sand and adding new concrete to the front of the concrete walls, or by placing more sand in front of the existing sand protection. Usually, however, this can not be done without to some extent reducing the arc of fire of the gun.

Many of our batteries are also deficient in overhead protection, since, at the time they were planned, high angle fire from naval vessels was not possible. It is possible to add the additional protection by increasing the concrete cover or by the addition of iron plates; but in very many cases the addition of this new protection can but result in the reduction of the available field of fire of the gun.

It is essentail, if our seacoast fortifications are to be kept up to date and to be efficient against modern navies, that our coast-defense guns should be at least as powerful as the guns which may be brought against them on shipboard; that is, our coast guns must be at least as great a caliber and must have at least as great a range as the naval guns.

As is shown by the accompanying table, most of our emplacements on shore were designed prior to the Spanish War, since which time there have been enormous advances in naval and seacoast ordnance, and, if our seacoast batteries are to be brought up to date, these smaller guns which they contain must be replaced by more powerful ones.

To adapt our emplacements to more powerful ordnance requires not only that new carriages should be constructed but that the very essentials of the emplacements should be altered, requiring the cutting away of large amounts of old concrete and the placing of large amounts of new concrete, the cost of which changes would be a very large percentage of the cost of new emplacements.

In fact, when everything is considered, the need of additional protection to the magazine, the need of more convenient ammunition service, together with the need of a complete rebuilding of the emplacement, at the loading platform and its vicinity, in order to adapt our older batteries to the new and larger guns; economy and efficiency will usually require that in emplacing new ordnance entirely new emplacements should be designed and built and that the old ones should be abandoned.

In designing and building new emplacements, of course, every effort should be made to provide for reasonable advances in the near future, for there is every reason to believe that such advances will continue, but experience in the past would seem to show that it is not within the limit of human intelligence to properly discount the advances of the future.

Consequently, based upon the same reasoning as is used by the Navy in its reports to Congress, that a certain number of battleships must annually be laid down if the Navy is to be kept fairly up to date, it would appear proper that the War Department should report to Congress that in order to keep our seacoast fortifications up to date it is necessary that each year a certain number of seacoast emplacements should be authorized.

What this number should be is, of course, a matter of judgment, but it is the opinion of the Chief of Engineers that we can not expect that our seacoast fortifications shall always remain even fairly up to date unless provisions are made annually for replacing from 4 to 6 per cent of our emplacements.

At present, as has been shown, there are no emplacements on our Atlantic and Gulf coasts, and only two on the Pacific coast that were not designed more than 10 years ago. Consequently, to enable us to catch up as it were, emplacement construction must for the next few years be carried on at a greater rate even than would be required by the percentage just stated. The Chief of Engineers considers it his duty, therefore, to urge that appropriations be made for emplacing each year for the next 10 years or so an average of not less than 8 major-caliber guns and 24 seacoast mortars.

In order to emphasize this matter, the Chief of Engineers, in his annual report submitted in the summer of 1915, inserted the following:

> When designed and constructed our seacoast batteries were thoroughly modern and fully adequate for the purpose for which they were intended, but the work of battery construction has in the past few years been allowed to practically cease and has not kept pace with the recent progress in naval development.
>
> It can not be too emphatically stated that the art of fortification is a progressive one. It must continually grow to keep pace with the new discoveries which give it special advantages or to meet and offset progress in the development of naval vessels and armament against which the forts are expected to contend. However carefully planned and constructed, a battery must always pertain to the date when completed and must be out of date in so far as relates to things which have been discovered or developed since the battery was planned.
>
> Seacoast defenses are designed to fight naval vessels and to thus protect certain cities, harbors, or other utilities from bombardment by an enemy's vessels within any of the area covered by the seacoast guns. In locating and designing batteries the range and power of the naval guns, as well as the number of such guns which can be brought against these fortifications, must be given consideration, and, unless our fortifications are to become obsolete, changes in any of the elements of naval offense must be met by corresponding changes in seacoast batteries, and these changes must in most cases consist not merely of modifying the older emplacements by affording additional protection for the gun platforms and magazines against the increased power of naval guns, or in mounting more powerful guns in these older emplacements, but rather in the construction of absolutely new batteries in new locations. The older batteries were necessarily designed and located so as to obtain the maximum effect with guns of the range of those to be mounted in those emplacements. If the guns which were to be mounted in those older batteries had been of longer range, the locations of the batteries would in many cases have been different, and if more powerful and longer range guns be mounted in those older batteries a large proportion of this increased power and range will in most cases be lost.
>
> For the above reasons it should be noted that a fixed project for seacoast defenses can never be adequate, and its obsolescence must begin before it can be completed.

For the first few years after the report of the Taft board was submitted, seacoast construction in this country, in general, was restricted to the completion of batteries previously begun, or to the installation of fire-control and other accessories. The new batteries that were begun were mainly in our tropical possessions and in the Panama Canal Zone.

About 1912, however, battery construction was resumed in the United States, principally on the Pacific coast, and studies were made of the work covered by the Taft board project for the defense of the entrance to Chesapeake Bay.

In its report submitted in the autumn of 1914 upon the project for the defense of the entrance to Chesapeake Bay, the special board which had been organized to consider the matter invited the attention of the War Department to recent developments in seacoast defense which appeared to make desirable a revision of all seacoast defense projects. About the same time the Chief of Engineers submitted the paper on obsolescence quoted above.

His attention having been thus called to the matter, the Secretary of War decided to organize in the War Department an agency known as the War Department Board of Review for the revision of seacoast defense projects. This board consisted of the Chief of Staff and his principal assistant, and of the Chief of Engineers, Chief of Ordnance, Chief of Coast Artillery, and the president of the War College. It at once commenced a study of all the projects for seacoast defense of the United States and, within about a year, submitted its recommendations as to the modifications which it thought should be made in these projects.

In a number of cases no additional emplacements were recommended, but in the more important defenses important modifications were reported as being necessary. In the meantime the 16-inch rifle had been developed by the Ordnance Department and was recommended for installation as the primary gun in the new fortifications, to be mounted generally on disappearing carriages providing for an elevation up to 30°. The 16-inch mortar was recommended as the standard mortar, to be emplaced in batteries of the same general type of the Panama Canal mortar batteries.

It having been brought to the attention of the board of review that there were on hand and not in use a number of 12-inch guns which had been manufactured by the Ordnance Department as "spares" to take the place of the standard 12-inch guns which had been installed in our seacoast defenses, as these guns wore out, and since it was probable that they would not be used for this purpose, the board of review recommended that these guns be emplaced immediately, 24 in the United States and 12 in the insular possessions, and in order to give these guns the maximum range possible, it was recommended that they be mounted on barbette carriages, permitting an elevation of from 30° to 35°.

The recommendations of the board of review as to the construction of 12-inch long-range emplacements have been carried out, but work on its other projects has not as yet been begun, although the Ordnance Department has done some work on the construction of the 16-inch guns and carriages. The reason for this is, that before work could be begun, the United States became involved in the recent war and during the war the efforts of the Ordnance and Engineer Departments were devoted to work immediately connected with the war, consequently it was not until about the time of the armistice that it was possible, without neglecting war work, to devote attention again to the seacoast-defense situation.

In the meantime, in connection with land operations abroad, there had been a rapid development of large-caliber railroad artillery and the War Department has referred to a committee of the General Staff the consideration of the question as to the effect that this development should properly have upon seacoast projects—that is, to what extent in the future our seacoast guns should be mounted on railroad cars and to what extent permanent emplacements should be built. Pending the receipt of the report of this committee, the work of designing seacoast emplacements has been temporarily suspended.

CHAPTER II.

ADMINISTRATION.

The duties of the Corps of Engineers of the Army are prescribed in certain paragraphs of Army Regulations with which all Engineer officers should be familiar. These paragraphs, however, are subject to amendment and are in fact frequently amended. Therefore, no attempt will be made to quote them here.

Among the duties of the Corps of Engineers as laid down by Army Regulations are the design and construction of permanent fortifications. In this country but few attempts have been made at the construction of permanent fortifications, except on our sea and lake shores and on the coasts of our insular possessions consequently so much of the duties of the Corps of Engineers as pertain to permanent fortifications have been performed almost exclusively in connection with coast fortifications.

The work of the Engineer Department is carried on under the command and supervision of the Chief of Engineers, who is assisted by certain officers and civilian employees in his office. The construction work is in charge of the district Engineer officers who are stationed in various places conveniently located with respect to the work. In order that this work may be properly coordinated and supervised, the Engineer districts are united into a number of groups called Engineer divisions which are under the supervision and general control of senior officers called division Engineers.

In connection with the fortification work, the Chief of Engineers receives assistance, especially in the way of advice, from the Board of Engineers, or, as it is sometimes called, the "Board of Engineers for Fortifications." This board consists normally of three Engineer officers of high rank who have had considerable experience in fortification matters, and, in addition, of a younger officer detailed as recorder of the board.

As was noted in the Chapter I, on historical matters, the Board of Engineers is a very ancient organization, dating back to about 1816. At one time the seat of the board was in Washington, later it was moved to New York City, where it is now.

In addition to the Engineer officers, who are regularly members of the board, Ordnance officers or officers of the Coast Artillery have occasionally been detailed on the board.

The principal duties of the Board of Engineers as laid down by Engineer Department Regulations, which have remained practically unchanged for many years, are as follows:

> There shall be Board of Engineers whose duty it shall be to revise, as may be directed by the Chief of Engineers, from time to time, projects of permanent fortifications required for the defense of the territory of the United States, and works of river and harbor improvement; also to consider and to report upon such other matters as may be referred to it by the Chief of Engineers.
>
> It shall be the duty of the members of the board, whenever required by the Chief of Engineers, to inspect and report upon any of the works of construction or other of the operations of the Engineer Department, the inspection reports to be made to the board and by it submitted to the Chief of Engineers, with such remarks as it may deem proper.
>
> The board shall consist of not less than three officers to be designated by the Chief of Engineers, with the sanction of the Secretary of War.

As will be seen from the above quotation, the functions of the Board of Engineers were formerly quite broad, and it was their duty when called upon to do so, to formulate a general project for the defense of any harbor, or to modify existing defense projects. In considering such a fortification project, it was their duty; to decide upon the general character of the defense to be provided; to fix upon the number of guns of different calibers which should be emplaced, and to select the locations for the emplacements; to make general designs for the emplacements themselves; to decide if a submarine mine defense was necessary and the character of the defense; to fix upon the number of searchlights needed, their location, etc. The recommendations of the board were made to the Chief of Engineers, and were forwarded by him to the Secretary of War. When approved by the Secretary of War they became the "approved project" for the defense of that locality.

In recent years, however, that is to say, since the organization of the General Staff, and the enactment of legislation providing for a Coast Artillery Corps and a Chief of Coast Artillery, who is ex officio a member of the General Staff, the duties of making or revising coast defense projects have devolved upon certain sections of the General Staff or upon special War Department boards formed for the purpose. Consequently, the Board of Engineers, in connection with seacoast defense, has no longer the important functions that it formerly had. However, there still devolves upon it the preparation of typical plans for seacoast defense structures.

The plans of the Board of Engineers are usually published to the Engineer Department in the form of Engineer Department mimeographs. Though not strictly confidential in the true sense of the word "confidential," access to the mimeographs is supposed to be restricted to the officers of the corps, or to other persons whose duties require it.

In the case of minor structures the mimeographs are usually quite simple, but when they relate to more extensive works, such as typical emplacements for large guns, they go into considerable detail and consist of a text and of a number of drawings. These show, not only the general outlay of the emplacements or other structures, with dimensions and elevations, but also in considerable detail the provisions for drainage, ventilation, heating, lighting, etc.

When any battery or other fortification structure is to be built in any Engineer district, as much information as may be necessary is sent the district officer. In the case of a battery he is notified as to the location selected for the battery, the number and caliber of the guns to be emplaced, the fields of fire to be covered by the guns and the general purpose of the battery. Appropriate mimeographs are sent to him, or he is referred to certain numbered mimeographs if they have already been furnished him.

With the data furnished him, it is the duty of the district officer to work out and prepare the detailed designs of the work. In so doing, however, he should not make the mistake, as has been done once or twice, of slavishly following the mimeograph drawing in all details. The mimeograph plans are, of course, made to suit general or average conditions and all of the general conditions are almost never fulfilled at any one locality. For instance, an emplacement mimeograph shows a certain angular field of fire for the gun with reference to the capital of the battery, but this may not in all cases suit the particular site. It is the duty of the district officer, therefore, to make a careful study of the site and its surroundings, especially as to the direction of the capital of the battery, the relative angular fields of fire of the different guns of the battery, the sides of the guns on which the magazines are to be placed, the elevation of the battery with reference to the surrounding ground, the possibility of concealment, etc. In addition, the district officer must work out all the details of the foundations, the drainage, water supply, ventilation, lighting, communications, etc., and in doing so he should include in his designs the latest improvements of which he may have heard, whether these were learned from mimeographs or in some other way.

The detail of plans of the structures are forwarded by the district officer to the division Engineer, who gives them careful study, and, by correspondence with the district officer, causes any alterations that he may consider necessary to be made. The plans are then forwarded to the Chief of Engineers, in whose office and in that of the Chief of Coast Artillery they are again examined. If found satisfactory, they are forwarded to the War Department for approval, and are finally returned to the district Engineer with directions to build the emplacements upon the designs as approved.

A similar routine is followed with the designs for range stations, searchlight buildings, mine defense stations, etc.

During the period of construction, Army Regulations place the structures within the exclusive control of the Engineer Department, but it is of course proper and suitable that the constructing officer should, from the very beginning and through all the stages of construction, freely and frequently discuss the various features with the local Coast Artillery authorities.

When a structure is completed, the district Engineer officer prepares the so-called "transfer drawings." These should contain not only the general plans of the structure but in addition when necessary, special instructions for the care of the structure or the care of the plant. In the case of a large battery, separate drawings should usually be prepared of the general design of the emplacement, of its electric system, of its drainage system, of its ventilating system, and so on. Some of these, of course, may sometimes be combined in a single drawing and, in the case of a smaller battery or a building, a single drawing may include data as to all these features.

When the transfer drawings have been prepared they are forwarded through the division Engineer to the Chief of Engineers with a letter announcing the completion of the battery or building. The drawings are then inspected in the office of the Chief of Engineers, and if found to be satisfactory they are forwarded to the War Department for formal approval. In due time instructions are issued by the Chief of Engineers to the district officer to formally transfer the structure to the garrison. At the same time, through military channels, the local Coast Artillery commander is ordered to formally receive the structure from the Engineer officer.

Upon receipt of these instructions at the locality, it is expected that the district Engineer officer and the local Coast Artillery commander, or an officer detailed by him, will make a joint personal inspection of the structure. After this inspection has been made, the keys, if any, are transferred by the Engineer officer to the Artillery commander, and any portable property is at the same time transferred by means of the usual invoices and receipts. The Artillery district commander is expected to give the district Engineer officer a formal acceptance of the structure, stating at the time such criticisms as he may desire as to the condition of the structure, its design, suitability for the purpose intended, etc.

Funds.

To carry on the fortification construction work of the Corps of Engineers, funds are necessary, and these funds are provided by congressional appropriations.

In the summer of each year there are prepared in the office of the Chief of Engineers, upon the basis of data received from district officers, estimates of the funds which it is considered should be appropriated for the fiscal year to begin on the 1st of July of the following summer. These estimates are submitted to the Secretary of War and, after more or less modification by his direction, are combined with other War Department estimates and, at the beginning of the next regular session of Congress, are submitted through the Treasury Department to the House of Representatives.

The various estimates are referred to certain committees of the House of Representatives, and in due time these committees hold hearings upon the different estimates.

During a committee hearing upon an Engineer Department estimate, the Chief of Engineers and his assistants who have special knowledge of the estimates are called before the committee and are closely questioned as to the detailed purposes for which the funds are desired and as to the needs of the particular amounts stated in the estimates. Upon the basis of the formal estimates before them and of the explanations which have been made to them, the committee prepares a draft of the fortification bill for the consideration of the House of Representatives.

Eventually the bill is passed by the House and goes to the Senate, where it is referred to a Senate committee. This committee also usually holds brief hearings and requests additional information as to certain items. The Senate committee then returns the appropriation bill to the Senate, usually suggesting a few amendments. The bill is then considered and passed by the Senate with or without amendments.

If the Senate has made amendments, the bill ultimately goes to a conference committee appointed by the two houses, which adjusts all differences and recommends to the House and Senate what may be called a compromise bill. This is ultimately passed by the House and Senate, and, when signed by the President, becomes a law.

Most of the appropriation items included in appropriation bills are for specific purposes, and of course the funds so appropriated can be expended for those purposes only. Not infrequently even an appropriation item has attached to it specific conditions, and of course the funds appropriated can be expended only under the conditions stated.

However, it was feared that a statement in the fortification appropriation bill that money was appropriated for the construction of a particular gun battery would be publishing to the world information which is considered desirable should remain secret. Consequently, the items in the fortification appropriation bill are usually expressed in general terms only. Thus, instead of stating that the appropriation is to cover the construction of a certain battery of a certain number of guns at one place, and another battery at another place, the bill contains a lump-sum appropriation for the construction of "gun and mortar batteries." Similarly with other items.

However, though the items of the fortification appropriation bill are usually stated in general terms only and legally are of very general application, yet it should be noted that the bill is drawn up only after committee hearings on the estimates, and during these committee hearings the Chief of Engineers, or his assistants, state to the committees the exact work intended to be done with the funds asked for. Though, therefore, in no way legally restricted by the wording of the law, the Engineer Department considers itself bound to allot and expend the funds appropriated for the specific purposes which were stated to the committee at the committee hearing and for no others.

The Chief of Engineers, after consultation with the Chief of Coast Artillery and with such other officials of the War Department as may be officially interested, allots the funds made available for the fortification work of the Engineer Department, to specific items of work in the different Engineer districts, and the prosecution of these items of work is then left to the district Engineer officers.

As has been stated, the construction work of the Corps of Engineers is carried on under the command and supervision of the Chief of Engineers, and does not in general come within the jurisdiction of the department commanders. However, in connection with the appropriation for the maintenance and upkeep of fortifications, which is ordinarily known as the appropriation for "preservation and repair," some special remarks appear necessary.

Up to a few years ago, it was customary for the Engineer department to consider the maintenance work done under the appropriations for preservation and repair, as essentially of the same character as the actual construction work. The appropriation would be distributed to the various engineer districts and it was left to the discretion of the district Engineer officer to select from the many items of needed work those which should be attended to. Consequently, the district Engineer officer performed this class of work, as he did the construction work, under the direction of the Chief of Engineers and independently of any supervision by the department commander or the local Artillery officers.

The department commanders are, however, responsible for the condition of military affairs in their respective departments and where a particular department contains sea-coast fortifications, the department commander is to a certain extent responsible for the condition in which these fortifications are kept. It is customary for each department commander to inspect all the fortifications in his department, at least once every year. During such inspection trips, it is quite probable that he will see some particular item of maintenance work which he may think should be given precedence and be attended to at once. If this should happen, all that he was able to do under the former method of carrying on the fortification maintenance work was to request the district Engineer officer to attend to this item, but he was without authority to direct that this particular piece of work should be done.

The present Chief of Engineers, Maj. Gen. William M. Black, just before being appointed Chief of Engineers, had served as department Engineer on the staff of the department commander of the Eastern Department. His attention was thus called to the somewhat anomalous condition of leaving entirely outside of the jurisdiction of the department commander, the preservation and repair of the fortifications, for the upkeep of which the department commander is in a sense responsible. Shortly after becoming Chief of Engineers, Gen. Black suggested to the War Department the desirability of modifying Army Regulations on this subject, and the result has been that the work of preservation and repair of fortifications is now divided into two different classes of work, first, work involving structural changes, and second, ordinary preservation and repair work not involving structural changes. This latter work has been placed under the control of the department commander, and, in so far as this work is concerned, the district Engineer officers are placed under the orders and supervision of the department commander. The other class of work, that is, work involving structural changes, remains under the supervision of the Chief of Engineers in the same manner as fortification construction work.

In actual practice the maintenance work is provided for in the following manner: Shortly after a fortification appropriation bill becomes a law a certain portion of it is set aside for repairs and modifications involving structural changes, and the remainder is assigned to ordinary nonstructural preservation and repair. The funds of the first class are allotted and distributed in the same manner as if they were for fortification construction work. The latter class of funds is distributed among the various military departments according to their respective needs, as shown by estimates previously received.

A department commander is informed by the War Department that a certain amount of the appropriation for preservation and repair has been set aside for maintenance work in his department. He then allots these funds, usually upon the advice of his department Engineer, among the different Engineer districts within his department and notifies the War Department of this allotment. He gives to the different Engineer officers such instructions with regard to the fortification maintenance work as he may desire.

As soon as the War Department is informed as to the desires of a department commander with regard to the distribution of the fortification maintenance funds, the Chief of Engineers takes steps to have the funds allotted, in accordance with the wishes of the department commander,. to the different district Engineer officers. The latter then expend the funds under the supervision of the department commander.

CHAPTER III.

ARMOR AND ARMAMENT.

Before going into the detailed discussion of fortification construction, which is the main subject of this work, it may be well to devote a short chapter to two closely related subjects, armor and armament.

ARMOR.

The object of armor is the protection of personnel, and, to some extent, of matériel, against the gunfire of the enemy. The kind of armor to be used must, of course, depend directly upon the character of gunfire against which it is to provide protection. Protection against gunfire can be obtained in several ways: By the use of earth, especially sand; by the use of masonry, stone, or concrete; and by the use of metal armor.

Earth protection is of course the cheapest and in some ways the most efficient, but in order to obtain protection against modern large projectiles a considerable thickness of sand is necessary. Furthermore, it is not possible to design a sand parapet sufficiently thick to give perfect protection without at the same time seriously interfering with the active features of the defense.

Masonry and concrete provide, for the same thickness, a greater resistance against the penetration of projectiles than do earth or sand, and in certain locations adapt themselves much better to the active features of the defense. They are, however, for the same bulk and also for the same amount of protection against penetration, much more expensive than earth or sand.

Steel armor, especially of the most modern type, opposes for a given thickness the greatest resistance to the penetration of projectiles. It is, however, extremely expensive, and on account of its high cost its use has been restricted to those situations where its peculiar efficiency counterbalances the high cost.

The use of brass armor in the form of a shield carried by a fighting man dates back before the dawn of history. The invention of methods of working iron caused the brass shield to be replaced by the iron shield, and until the early middle ages it was customary for all heavily armored soldiers to be provided with shields.

Increase in skill in working iron permitted the principle of a shield to be extended from the original shield to body armor covering practically the entire body, and, in the case of a mounted man, his horse also. The increasing power of missile weapons, however, made an increase in the thickness of armor necessary, until soon the weight of body armor became too heavy for a man to carry when on foot, and rendered him unwieldly even on horseback. Finally, not many centuries after the invention of gunpowder, armor fell into general disuse, except in the case of helmets or cuirasses carried by certain kinds of mounted troops.

Armor was introduced as a protection for ships shortly before the time of our Civil War, and during that war its efficiency was proven. Because of its relatively great resisting power to the penetration of projectiles in proportion to its weight, and since in ship construction the question of weight is one of prime importance, a resort to steel armor for ship construction became necessary in spite of its high cost. On shore its use has been far less common than on shipboard, because in shore batteries there is ordinarily ample space to make possible the use of the much cheaper earth or sand protection and the question of weight is usually of no importance.

During the last two decades of the last century, metal armor, especially cast iron, was much used in fortification construction in certain sections of Europe. Some of the land guns were mounted in armored turrets similar in general character to the naval turrets of the day, and some were mounted in armored casemates the fronts of which were somewhat similar to the fronts of turrets. Furthermore, armor was used also as the protection against overhead fire in certain mortar batteries, and also to protect observation stations and disappearing searchlights.

In this country the use of armor on land has in general not met with much favor except for a few special purposes. Bullet-proof shields have been used with the limbers of field guns, and shields sufficient to withstand the projectiles of field guns have been used on field guns. The 6 and 8 inch barbette seacoast guns have likewise been provided with shields, and emplacements for these guns had to be so designed that the shields could be used. Armored casemate mounts, however, for seacoast guns have never been used, and the only actual use of the armored turret has been in the fortifications of Manila Harbor.

Recent wars, however, have given quite an impetus to the use of armor in connection with land operations. Armored locomotives and cars were used in the South African War, and were developed in this country to a considerable extent in connection with possible operations in Mexico. The armored automobile was utilized to some extent in the early stages of the recent war and from it there have been developed the so-called tanks.

Apparently, during the war, there has been practically no development of steel armor in connection with emplacements of heavy guns, nor would it appear that any further development of this matter is probable since the present tendency appears rather toward making the guns portable than to providing for them heavily armored permanent emplacements.

ARMAMENT.

The Ordnance Department manufactures the guns and the gun carriages to be used in seacoast defense. When these guns are to be mounted in fixed emplacements, the Engineer Department builds the emplacements.

GUNS.

The guns for which the Engineer Department has been called upon to provide emplacements are of many different calibers:—less than 3-inch guns, 3-inch, 4-inch, 4.7-inch, 5-inch, 6-inch, 8-inch, 10-inch, 12-inch, 14-inch, and 16-inch guns, and 12-inch and 16-inch mortars.

This multiplicity of different calibers originated under a number of different circumstances, and the best-informed officers are now in favor of reducing the number of different calibers, the tendency being toward the adoption of a standard small-caliber gun, a standard medium-caliber gun, a standard large-caliber gun, and a standard large-caliber mortar.

The 4.7-inch gun was introduced into our seacoast defenses during the Spanish War. At that time the number of rapid-fire guns available in this country was very small, and it was necessary to make purchases abroad. The 4.7-inch Armstrong gun was available at that time for purchase and was about equivalent in power to our standard 5-inch gun. Consequently, a number of these 4.7-inch Armstrong guns were purchased. At first they were installed in hastily constructed emplacements at a large number of our seacoast forts. This work was done with all the rapidity possible, using any sites available, and of course, as was to be expected, a number of the sites chosen at that time proved afterwards to be far from suitable. Furthermore, the arrangements for magazines and storerooms which had been hastily improvised, were not, in general, satisfactory for permanent use. As a result a number of these guns had to be reemplaced, and in so doing, the tendency has been to group them into batteries of three or four guns each. It is not probable that any more guns of this caliber will be purchased or manufactured, and consequently, before long, this caliber of gun will have been eliminated from our seacoast defenses.

The 5-inch rapid fire gun was decided upon at a time when it was thought that the principle of rapid fire could not be applied to a larger gun. This has proven not to be true, and rapid-fire 6-inch and 8-inch guns can now be made. Consequently the 5-inch gun also may be considered as an obsolete type.

The 6-inch guns first made were not fitted for rapid fire and a number of them were mounted on disappearing carriages, with which what is called rapid fire is not possible. It now appears that this gun is well adapted to rapid fire and consequently it has become a standard medium-caliber rapid-fire gun.

The 8-inch gun was the first one for which a satisfactory disappearing carriage was developed. It was not long, however, before a similar carriage was developed for the 10-inch gun, but after that there was quite a delay before a satisfactory 12-inch carriage could be manufactured. In the meantime quite a number of 8-inch and 10-inch guns were manufactured and were mounted in a few cases in barbette emplacements, but to a greater extent on disappearing carriages. The development, however, of a satisfactory 12-inch disappearing carriage soon did away with the manufacture of 8-inch and 10-inch guns and carriages. Most of the remaining 8-inch guns were dismounted during the recent war and, although a number of 10-inch guns are still in commission, the 10-inch gun also may be considered as an obsolescent type.

The first of the 12-inch guns to be emplaced for seacoast defense were but 30 calibers long, and as a number of these guns had been manufactured and were available, and a satisfactory 12-inch disappearing carriage had not at that time been developed, a very large number of these guns were mounted on barbette carriages, even in locations where disappearing carriages would have been more suitable. As soon, however, as the disappearing carriages became available it became customary to mount practically all new 12-inch guns on disappearing carriages.

Although the 30-caliber 12-inch gun was much more powerful than the 10-inch and 8-inch guns, it was soon found to be deficient in power at extreme ranges, and a change was made to the 35-caliber gun and emplacements for a number of these longer guns were built. It soon appeared, however, that the powder pressure necessary to obtain the full initial velocity out of this long 12-inch gun was so great and the consequent internal temperature so high that the erosion in the guns was excessive. On account of the apparent short life of these guns it was decided to substitute for them in future emplacements the 14-inch gun, which with lower powder pressures would, on account of the heavier projectiles, have at long ranges the same or even a greater striking power. This change was recommended by the Taft Board. It was for this reason that the 14-inch gun was introduced into seacoast work. Subsequently it was improved and became the standard large-caliber gun at the time the Panama and later Philippine batteries were designed.

Many years ago, as an experiment, the Ordnance Department constructed a 16-inch gun. This remained for many years at Sandy Hook out of use, but a few years ago it was taken to Panama and installed on a disappearing carriage specially constructed for it.

In very recent years, however, the manufacture of very long 16-inch guns, up to 50 calibers in length, has been found to be perfectly practicable, and the present policy of the War Department is that the 50-caliber 16-inch gun is to be the standard major-caliber weapon hereafter.

Mortars.

Prior to the appointment of the Endicott Board there had been developed and were in use in this country many different calibers of mortars, from the small 4-inch portable Coehorn mortar for use in siege works up to a large 20-inch mortar for seacoast work. All of them were smooth bore and muzzle loading and their length did not exceed 3 feet or so as a maximum. At the time of the Endicott Board, however, the efficiency of the mortar for seacoast use had apparently been so effectually demonstrated that the Ordnance Department took up the manufacture of breech-loading howitzers of considerable length. Since these howitzers were to be used in the same manner as the older mortars, the name "mortars" was applied to them and has stuck to them ever since.

The first guns of this type were the 12-inch howitzers or mortars and this remained until a few years ago the standard seacoast mortar.

By the time the Panama fortifications were under consideration, a satisfactory 12-inch mortar, 15 calibers long, had been developed by the Ordnance Department, and this then became the standard type. More recently still a 16 inch mortar or howitzer has been developed, and it is understood it is this mortar that will hereafter be furnished for seacoast use, practically to the exclusion of smaller sizes.

GUN MOUNTS AND CARRIAGES.

At the time that our modern fortifications were started the only types of mounts in seacoast use were the barbette mount and the turret. Disappearing guns were in their infancy, although a number of types had been invented in this country and the experiments with some of them had been satisfactory.

About the first successful type of disappearing gun carriage to be invented was the "King carriage," the invention of Maj. William R. King of the Corps of Engineers. This type of carriage was a modification of the standard barbette carriage in use at that time, the essential difference being that the gun carriage instead of sliding with friction up a slightly inclined plane when the gun was fired, slid downward at an angle of about 30° behind the parapet, raising vertically by means of a cable a heavy counterweight which soon overcame the energy of recoil and brought the gun and top carriage to rest. This carriage was developed shortly after the Civil War and was successfully tested at Fort Wadsworth, New York Harbor. At this time, however, as was stated in the historical sketch, practically no new seacoast defenses were being constructed in this country and consequently this type of carriage was never adopted for use.

In the early eighties, however, with the revival of interest in seacoast defense matters, a number of types of disappearing carriages were experimented with until there was developed the Buffington-Crozier type. This type of carriage was first developed satisfactorily for the 8-inch rifle and subsequently for the 6-inch, the 10-inch, the 12-inch, the 14-inch, and 16-inch rifles.

As far as is known the first guns ever mounted in a turret were those on the original *Monitor*. As a result of the victory over the *Merrimac* the turret became the standard method of mounting large guns on shipboard, the dreadnaught battleship of the present day having all of its major-caliber guns mounted in turrets. As a rule 2-gun turrets have been the standard, but in the very recent past a 3-gun turret has been adopted, in our Navy at least, as the standard.

In spite of the great success of the turrets for mounting naval guns and their occasional use in mounting land guns in Europe, they have never become popular for mounting land guns in the United States.

Between the years 1911 and 1918 there were designed and built on one of the islands in Manila Bay two turrets, in each of which were installed two 14-inch guns. The idea of mounting the guns on this island in turrets originated with Capt. John J. Kingman, Corps of Engineers, then on construction duty in the defenses of Manila, because, on account of the small size of the island, it was the only method by which a sufficient number of guns could be emplaced on it. According to his original proposition it was proposed that the Engineer Department should purchase from the Navy Department and install on the island the standard naval turrets with their guns. It was later decided by the War Department that the manufacture of mounts for seacoast guns pertained to the Army Ordnance Department and this department was therefore directed to design and manufacture the turrets and carriages for these guns. Much delay, however, resulted, and it was not until 1918 that the turrets were finally completed and the guns mounted.

The project for the defense of the eastern end of Long Island Sound as revised in 1916 by the War Department Board of Review, included a turret for two 16-inch guns at one of the forts in these defenses. The installation of this turret was delayed by the breaking out of the big war and since the war, although the matter has been much discussed, no definite decision seems to have yet been taken. Should it be decided to install these guns in a turret it is the opinion of the

Engineer Department that the quickest and most satisfactory arrangement would be to purchase a naval turret from the Navy Department. The reasons for doing this are as follows: A turret is a very complicated piece of machinery and it is the general experience of human nature that no new and complicated piece of machinery was ever invented that did not, when first constructed, develop a number of weaknesses. Turrets have been in use in the Navy for many years and practically all the weak points have been shown up and removed; consequently, the chances of obtaining a satisfactory turret would appear to be many times greater by adopting bodily the naval turret which has already been perfected, rather than by trusting to the hasty development of a new type of turret by a department practically without previous experience in such a matter.

COMPARISON OF DIFFERENT TYPES OF MOUNTS.

The relative merits, advantages, and disadvantages of the three types of seacoast gun carriages, viz, the barbette, the disappearing, and the turret mounts, have been much discussed, and some 16 or 18 years ago a number of articles on the subject appeared in our service journals, which can be referred to by persons specially interested in these affairs. The articles, of course, discussed the matter according to then existing conditions. Since that time, however, as will appear later, many new conditions have arisen, and it would appear well to briefly review the matter here.

The facts would appear to be that each of these types of mounts has its advantages and its disadvantages, and while each would appear to be the most suitable for certain conditions, no one of them is the best suited to all.

The Barbette Mount.

The barbette mount has the great advantage of being capable of firing in any direction horizontally and to almost any angle of elevation. When fitted, however, for fire horizontally or at an angle of depression throughout the whole 360° of traverse, the gun and carriage must necessarily be exposed to view above all surrounding objects and must be very conspicuous and give the minimum protection to the detachment. If mounted lower and so as to be less conspicuous, its field of fire will be somewhat reduced.

With the small caliber guns, where fixed ammunition is fired and where the ammunition does not weigh too much to make loading possible when the gun is at any angle of elevation, the barbette mount has the additional advantage of permitting the most rapid fire. In the larger caliber guns, however, where the ammunition is so heavy that the gun must be loaded when in a practically horizontal position, or even at a slight angle of depression, it is evident that a barbette gun must have its elevation changed from that used in firing down to the loading position, and when loaded, must be again trained in elevation. This does not permit the rapid loading and firing which is possible with the diasppearing gun where the gun recoils into the same loading position and with its breech at the same elevation whatever be the angle of elevation at which the gun may be laid at the time.

Incidentally, also, the barbette mounts for large guns heretofore used in this country have been somewhat crude in their provisions for ammunition service.

When a barbette gun is trained in elevation it rotates about a horizontal axis through the trunnions, and if the angle of elevation be considerable and the length of the gun in rear of the trunnion be quite great, as is the case with large guns, the breech of the gun when trained for a high angle of elevation drops down considerably below the trunnions. This makes it necessary, therefore, either that a gun should be so mounted that its trunnions are at a considerable height above the base on which it rests, or else that a space be provided into which the breech of the gun may recoil when the gun is trained high in elevation.

In the standard form of barbette mount heretofore adopted in this country for the larger guns, this depression of the breech has been made possible by raising the trunnions high above the ground. The gun must be loaded in practically a horizontal position and the men actually doing the loading must for convenience stand upon a platform from 4 to 4½ feet below the axis of the gun. This has been made possible by attaching to the gun carriage a long horizontal metal platform which rotates as the gun is moved in azimuth. When the gun is elevated and the breech depressed the breech drops down through a slot to the floor of this platform. This platform extends far enough to the rear of the gun to give room for the ramming detachment. The only means heretofore provided with these barbette carriages, for raising projectiles up to the gun is by the old-style crane, and loading guns with projectiles raised by the crane has been found not to be a very rapid process. Consequently, these barbette guns have been much slower in loading and firing than the disappearing guns of the same caliber.

However, in the type of carriage provided for the high-angle 12-inch rifles, of which quite a number have recently been emplaced in this country, the base of the carriage has been set in a large gun well, and when the gun is elevated the breech is depressed through a slot in a metal platform covering this gun well and revolving in azimuth with the gun. When the gun is horizontal the breech projects slightly behind and outside the gun well, and the projectile carried on the usual type of projectile truck can be brought right up to the breech of the gun and can be rammed into the breech in the same manner as is done with the disappearing carriage. The loading can, therefore, be done almost as rapidly as in the disappearing carriages. It is necessary, however, that after the gun has been fired once it be brought down to the horizontal before it can be loaded, and after the loading is completed the gun must once again be trained in elevation. The time necessary for this large angular movement exceeds that required for the disappearing gun to rise into battery and to recoil after firing, so that even with the improved barbette mount the rate of fire must be slower than with the disappearing carriage.

It is understood that the barbette mounts proposed by the Ordnance Department for use in the future with large guns, approximate, in general characteristics, to those used with the recently emplaced 12-inch guns, at least in so far as the possibilities of rapid loading are concerned.

Disappearing Mount.

The disappearing carriage has the great advantage that the gun in the loading position is invisible and, in batteries made on the horizontal crest principle, there is nothing that can be seen by the enemy to show the location of the guns or the number of any battery. Concealment is therefore attained. This type, in addition, has the great advantage of giving the maximum protection to the lower and more delicate parts of the gun carriage and to the detachment, not only against direct hits but also against the fragments of a projectile that may fall short and detonate. Although it might appear that, against projectiles with a large angle of fall, the protection given by a disappearing emplacement against a direct hit is much more apparent than real, yet the experiments at Fort Morgan in the spring of 1916 showed clearly that against the fragments of projectiles striking short and detonating, the parapet of a disappearing emplacement does provide much real protection to the detachment. In addition, there is no doubt that the feeling of protection possessed by the detachment should make the handling of the gun in action much better and more reliable than when the men feel that they are exposed.

When the disappearing carriages were first proposed and developed it was expected that combats between ships and seacoast forts would be carried on in general at comparatively short ranges, and consequently high angles of fire were not considered necessary, nor was protection considered necessary against projectiles having more than a comparatively small angle of fall. Consequently, 15° was the maximum angle of elevation possible with the early disappearing carriages developed in this country.

Within the last decade, however, there has been a rapid increase in the range at which guns have been fired, either in experiment or in actual combat. Naval engagements have been fought at ranges approximately 25,000 yards and naval guns are now mounted so as to be able to fire at as high as 45° elevation.

In a combat with ships capable of such high angle fire and having such a long range, a seacoast battery with guns whose elevation is limited by the carriage would be at a great disadvantage. Consequently, there has been a demand by the Coast Artillery that the seacoast guns hereafter to be emplaced should be capable of firing at an elevation which will give the maximum range of the gun.

The original disappearing carriages were designed for 15° of elevation, and this remained for many years the standard. In more recent years, however, some of these carriages, especially those at Panama and in the tropical possessions, have been modified so as to permit 20° of elevation. Much beyond this it would appear impossible to go with the present type of disappearing carriage or, in fact, with any type of disappearing carriage.

On account, therefore, of the impossibility of providing sufficient angles of elevation it is believed that the disappearing carriage must in the future be considered as unsuitable for seacoast defense generally, and as a type of carriage not to be used except in a few special locations where, for special reasons, it is considered advisable to withhold certain guns from long-range use for firing later at comparatively close ranges. Under such conditions, on account of the ease of manipulation and rapidity of fire, the disappearing carriage may still prove extremely satisfactory.

The disappearing carriage also has an additional great advantage in that at whatever angle of elevation a gun may be laid, the axis in the loading position is practically horizontal, and its breech is at practically the same elevation, so that the projectile trucks once set may be used for rapid loading irrespective of how the gun may be laid in elevation. This permits the gun to be kept constantly laid on the target both in azimuth and elevation. When tripped, it rises promptly into the proper position for firing and as it fires it recoils into exactly the proper position for loading. This type of carriage therefore lends itself to the most rapid handling of ammunition and rate of firing, the 12-inch disappearing guns having been actually loaded and fired at less than 20-second intervals as against practically 2-minute intervals for barbette guns of the same size.

The disappearing carriage of the standard and most used type has, however, the great disadvantage that it practically limits the possible arc of traverse to approximately 170° and also limits the possible angle of elevation to about 30°. In the older types of disappearing carriages this limit to the elevation at which the guns could be fired was in some cases 20°, but usually 15° only.

The restriction in the horizontal angle through which the gun can be fired is encountered, not because the gun and carriage if mounted in the open could not be traversed through the full 360°, but because of the existence of the parapet which is necessary to give the advantages of concealment of the position of the gun while loading and of protection to the gun carriage and detachment.

In order that the parapet may offer the maximum protection, it must be built as close as possible to the gun—that is, with its vertical face but a foot or so in front of the position of the muzzle of the gun when the gun is in the loading position, and the crest of the parapet must be at such a height that the gun will just clear when it rises into the firing position when set for fire at the maximum angle of depression at which it is proposed to use the gun.

In order that the gun may be fired directly to the rear of its normal direction of firing, ample space must be provided for its recoiling into a loading position when fired to the rear, and the parapet must therefore be placed so far to the front (that is, in the direction of the breech end of the gun when firing to the rear) that the breech will not strike the parapet during recoil.

In the standard form of disappearing carriage, the vertical axis about which the gun and carriage rotate in azimuth is usually from 8 to 12 feet forward of the center of length of the gun in loading position, or, in other words, from 16 to 24 feet nearer to the muzzle than to the breech of the gun.

If, therefore, a disappearing emplacement is to be designed so that the gun can fire to the rear, it is necessary that the parapet be moved from 16 to 24 feet farther away from the axis of the gun well, and if the emplacement is to be used for firing at any angle of depression the height of the parapet must be much reduced.

Not only will such a parapet provide much less concealment and protection from the enemy's projectiles, but it would also have the great disadvantage that the muzzle of the gun when fired will not project over the parapet but will be to the rear of the rear face of the parapet. Consequently, the blast of discharge will be reflected back into the emplacement. It has been found to be necessary that the muzzle of the gun project at least 5 feet over the crest of a parapet in order that none of the direct blast may be reflected back into the emplacement. To fire a gun with its muzzle well to the rear of the parapet would be to endanger the entire detachment, as well as the material in the emplacement from damage by blast.

Although the standard and most generally used form of disappearing carriage limits the horizontal angle through which the gun can be fired, this has not been true of two special types of disappearing mounts which have been used or suggested.

In one of these types the gun well, instead of being cylindrical, as is usual, was made annular, and consists of the space between two cylinders. The counterweight hung down in this annular space and rotated when the gun was rotated in azimuth. This type of carriage was tried with the 10-inch guns in certain of our seacoast batteries, but is understood not to have been a complete success.

The other type of carriage is the most modern all-around type of 16-inch disappearing gun carriage designed by the Ordnance Department. In this the well is extremely large and the axis of the well passes unusually near the center of the length of the gun in the loading position. Building the parapet a few feet in advance of its ordinary position and yet not so far but that the muzzle of the gun in battery projects far enough over it, there is room for the breech to recoil even should the gun be aimed directly to the rear. The gun, however, can not be loaded in this position, and before it can be loaded it must be traversed into some azimuth in which loading is possible.

Turret Mounts.

The turret mount has the advantage that it may be fired in any horizontal direction and can be adapted to use at a degree of elevation which will make use of the maximum range of the gun. This mount provides almost complete protection for the gun carriages and for the personnel, and for all portions of the guns except the ends projecting outside of the turret. It also lends itself well to mechanical means of loading, and in the latest forms of naval turrets an extremely rapid rate of firing has been obtained, even with guns as large as 16-inch.

Turrets have, however, the great disadvantage of enormous cost and though comparatively invulnerable, yet experience has shown that in action it may not infrequently happen that a turret as a whole may become jammed either as the result of a direct hit or a hit around the base. When this occurs, of course, the turret becomes practically useless, as the guns can be fired in but one direction only.

Where there is but little space and where it is a question, as in ship construction, of keeping down the weight as much as possible, the turret is undoubtedly the best type of mount, in spite of its cost and other defects. Where there is no scarcity of space and ease of handling and rapidity of loading are to be desired, the disappearing carriage is probably better.

Portable Mounts.

Prior to the recent war it seems to have been generally considered by military experts that the 6-inch direct fire gun, and possibly the 8-inch or 9-inch Howitzer, were the largest guns which were capable of being transported upon carriages from which they could be fired. That this was not true was shown by the surprise sprung by the Germans in their campaign in Belgium in 1914. They proved their ability to transport and to use guns of much larger caliber than those mentioned, with the result that the guns mounted in the Belgium permanent fortifications were hopelessly outclassed and these fortifications were soon destroyed.

This gave a great impetus to the development of portable artillery, both for transportation on paved highways and on railroad trains, with the result that nearly a year before the war closed the Germans had brought up and were firing a gun having a range of some 60 or 70 miles. This gun was, however, fired from an elaborate emplacement. The Allies mounted on railroad carriages guns of 14-inch caliber which had a range of 18 miles.

It would appear that these portable railroad guns are mounted on two essentially different characters of mount. First, those to be fired from the cars themselves with but a slight preparation of the foundation; second, those which were not intended to be fired from the cars themselves but which, before firing, were to be transferred to prepared bases, after which the cars, or at least the wheels of the cars, were to be removed.

The first type has the great advantage that it can be put in action quickly, but the great disadvantage that it permits of being fired only in the direction of the length of the car, or within a degree or two of azimuth on either side of the axis of the car. Consequently, when its azimuth has to be frequently changed, the car has to be removed to a track laid in a curve, the general control of azimuth being obtained by the exact place in the curve at which the car in placed and the final setting in azimuth by moving the gun slightly on the car.

When firing upon a fixed land target which can not be moved, such as a town, manufacturing plant, railroad station, etc., this small degree of control in azimuth may be all that is necessary, but it is evident that a gun mounted in this manner can not be used satisfactorily in firing against ships, unless at anchor, and certainly can not be made to follow the motions of a rapidly moving ship.

In the second type of carriage, where the gun has to be moved from the car to a base prepared in advance, the railroad car is, in reality, only a form of portable or travelling carriage. It has the advantage of a greater range in azimuth, for when the gun is once mounted on such prepared base its azimuth is practically unlimited. It has, however, the great disadvantage that it can not be put in action or withdrawn from action rapidly, since the preparation of the base and transfer of the gun from car to carriage will require considerable time, as will the reverse process of making the gun again portable.

That guns mounted on portable carriages may fulfill an important function in seacoast defense is undoubtedly true, but exactly to what extent they should be used and to what extent the fixed emplacement should be retained is a question for the future to decide.

PROJECTILES.

The size and weight of projectiles vary, not only with the size of the gun from which they are to be fired, but for other reasons. In other words, the Ordnance Department, in a number of cases, furnishes for a single gun, projectiles of more than one kind.

In some cases the different types of projectiles furnished for the same gun differ mainly in length and weight. Thus for use with the mortars, long heavy projectiles are issued for work at comparatively short range where the striking velocities are limited, and lighter and shorter projectiles for work at very long ranges to attain which it is necessary that the shells go very high. In the latter case the striking velocity is great and this makes up for the small weight of the projectiles.

In other cases the projectiles, though of practically the same size and weight, differ principally in the thickness of the walls of the shell, the size of the chamber, and the amount of explosive carried. Strongly built shells with thick walls are necessary for armor piercing, in spite of the fact that they make it necessary to limit the amount of explosive carried. On the other hand, for inflicting the greatest damage on unarmored ships or the unarmored portions of armored ships, thin-walled shells carrying large quantities of explosives are most efficient.

In connection with the subject of projectiles there is one development of the last few years which has somewhat seriously affected the Engineer Department; that is the comparatively recent change in the shape of the projectiles for large guns.

A few years ago it was discovered by experiment that by lengthening the point of the projectile, that is, by increasing the radius of the curve of the ogive, the resistance which the air offered to the passage of the projectile was much reduced, with a consequent increase in the range and velocity of the projectile, and a flattening of the trajectory.

Apparently the present adopted standard is that the radius of the ogive should be approximately equal to 7 calibers, which makes the length of the point more than 2½ calibers; thus with the 14-inch projectiles the radius of the ogive is approximately 97 inches, which brings the tangency of the ogive and the cylindrical portion of the projectile about 36 inches from the point. The cylindrical portion is about 27 inches long, which makes the total length of the projectile 63 inches, or about 4½ calibers.

The projectile hoists which were installed in the early emplacements were, of course, designed to raise the projectile of the day, and though some allowance was made for slight increases in length the allowance was, in general, not sufficient for the great increase caused by the introduction of the new type. Consequently it became necessary to change practically all the hoists which had been installed prior to about 1911.

This has been done under an appropriation for modernizing and it has now been completed in all 12-inch emplacements, and is about to be completed in all 10-inch emplacements still to be retained in commission. The 8-inch gun being an obsolescent type, it has been decided to be not worth while to change the projectile hoists in the emplacements for that caliber of gun, nor has this been done in a number of the very old 6-inch batteries, the projectiles of which can be carried by hand.

Besides merely lengthening the projectile, this change in shape indirectly had another very important effect. The center of gravity is left only an inch or two to the rear of the point of tangency of the ogive and cylindrical portions. This renders the projectile somewhat difficult to roll on a horizontal table or on horizontal rails because the center of gravity is so near the end of the cylindrical surface on which the rolling is done that any slight resistance is apt to swing the projectile around and cause it to roll in another direction.

CHAPTER IV.

MATERIAL USED IN EMPLACEMENT CONSTRUCTION.

In the earliest permanent fortifications of which we know, the faces of the walls exposed to the enemy were built either of stone or of brick masonry and this type of construction persisted until after the introduction of gunpowder.

The earlier cannon were of exceedingly low power and the flight of the projectiles was quite erratic, and though they soon showed their ability to damage masonry walls, considerable time was required to do this, and it must have seemed to the fortification engineers of the day that if the walls could be made a little more resistant to cannon fire they might be able to withstand considerable bombardment. The attempt was therefore made to strengthen the walls by increasing the thickness of their faces, by building counterforts in the wall, by the use of relieving arches, etc.

The use of these expedients made the walls much more resistant but in course of a few centuries the power of cannon increased so much that they were able to destroy these strengthened walls also, and it was found that no masonry construction could withstand the continuous bombardment of cannon. Consequently the use of masonry was entirely done away with, wherever exposed to continued land bombardment, and earthen parapets were substituted instead.

At first sight it would appear that if masonry can not withstand cannon fire, earth can not either—that is, any projectile that can destroy masonry will certainly penetrate and destroy a mass of earth. This is undoubtedly true, but if a projectile passes through a mass of earth, the loose earth above falls into and fills the hole made by the passage of the projectile and the net result is merely a slight groove in the surface. If a projectile enters into a mass of earth and explodes, some earth is blown up into the air. A considerable portion of it, however, falls back into the crater from which it came and although a well-pronounced crater may be made, the same amount of earth is in the parapet as was there before, although somewhat differently placed. A second projectile entering the earth and exploding near by will not improbably fill, or partially fill, the hole made by the first, and so on. If it is possible by night to repair some of the damage done by the day, an earthen parapet will withstand an almost indefinite bombardment.

Consequently, in all land fortifications earthwork has for many years been relied upon as the main agency to resist the enemy's projectiles.

For several centuries after it had been found necessary to discard in land forts the use of exposed masonry walls, such walls were still used on the sea fronts. This was considered possible because the fire from ships was always more or less erratic, the ships being subject to wave action; and it seemed quite improbable that a sufficient number of projectiles from a ship would strike a wall close enough to the same spot to have any real battering effect. Furthermore, the ships at the time were built of wood and were thus quite vulnerable; they were propelled by sails, which rendered them, to a certain extent, at the mercy of the wind and waves. It was clear, therefore, that they would never dare to attempt a sufficiently prolonged bombardment of a masonry land fort to be able to seriously damage the masonry walls.

However, about the time of our Civil War it became customary to use armor to protect the exposed sides of warships. The introduction of steam a few years before had made it possible for the ship to go where it would and to approach or retreat from a fort as it desired. It thus became possible for armored steamships to attempt a prolonged bombardment of a seacoast fort, and it was soon shown that by such a bombardment the masonry walls of the sea front could be destroyed. It, therefore, became necessary, on the sea fronts of the seacoast forts also, to do away with masonry walls and to rely on earthen parapets to resist bombardment.

SAND.

Consequently, it is the modern idea that in seacoast fortifications, as in land forts, the main protection against the enemy's projectiles is the mass of earth, or as it is called, the "parapet," and that concrete protection is to be used only on special occasions, such as in the blast apron in front of the muzzle of the gun, where earth would be blown out when the gun is fired, or in retaining walls where it is necessary that the rear of a mass of earth stand vertically.

Although referred to under the general name of "earth," it is preferable that the mass of a parapet should be composed not of clay or loam but of sand, since it has been found that a projectile entering a mass of sand appears to have a tendency to deflect upward and to leave the sand without penetrating very far. In other words, projectiles striking in sand have a tendency to ricochet in much the same manner as they do upon striking water.

This tendency has been greatly increased in the recent past by the modifications made in the shape of projectiles in the way of increasing the length of the point. This change was made to decrease the resistance offered by the air to the flight of the projectile, and to thus increase the range of the gun, but indirectly it has had the effect of increasing the tendency of a projectile to ricochet upon striking sand. As a projectile of this type enters sand it packs under the point and tends to deflect the latter upward. This tendency is so great that it has been found that it is almost impossible to make lengthy projectiles penetrate very far into a sand parapet without curving upward and coming out through the top.

This was very noticeable in the experiments conducted at Fort Morgan, Ala., in March, 1916, when naval vessels fired at an emplacement specially constructed for the purpose. All the projectiles fired by the Navy, that did not detonate upon impact, emerged from the sand after a short penetration only. On practically horizontal surfaces the projectiles, even though striking with an angle of fall of 18°, penetrated not more than 3 or 4 feet deep before they curved upward and emerged from the sand, and even where detonation occurred apparently at the time of greatest penetration, the craters were not more than 5 feet deep.

Not only did the projectiles ricochet from the horizontal sand surface, but this was also the case where they struck the front slopes of the parapet. In one case a projectile struck the exterior slope of the sand parapet making an angle of approximately 40° with that surface. It penetrated the sand only a short distance and emerged 40 feet away from the point of entrance. Apparently at no time was it more than 8 feet below the surface.

Ordinary earth and clay do not seem to possess this tendency to deflect projectiles to anywhere nearly as great an extent as sand, and consequently sand should be used in parapets instead of earth and clay, even if it is necessary to go to considerable expense to obtain it. This is especially true of the parapets in front of guns and in front of and on top of magazines.

SAND FILL.

On account of the comparatively high cost of concrete as compared with sand, attempts have frequently been made to substitute sand for a portion of the mass of concrete in emplacements. Thus, beneath the floors of the first-story rooms sand has been used in place of filling up with concrete. Occasionally also, especially in the smaller emplacements, sand has been used under the loading platform, as will be noted on some of the drawings. (See Pls. V, VII, and IX.) There have also been cases where voids can well be left in the concrete and these have been filled with sand. This last, however, is believed to be hardly necessary as a better method is to build rough box-like frames and to cover them completely with concrete, thus leaving actual voids in the mass. However, in the more modern batteries it has been customary, wherever a void has been left, to place a door into it and to prepare it so that it can be used for storage purposes if needed.

Wherever sand is to be used for filling voids and is to be covered by concrete it is of course necessary for the future safety of the concrete that the space be entirely filled with earth or sand, and that there be no space left for subsequent settlement of this earth or sand filling. In order to insure this, it is necessary that there be no place left for the sand to escape. Thus, if the sand filling has to be placed upon a mass of broken stone, the broken stone must first be covered with a ayer of concrete, for otherwise the sand in time could jar down into the voids of the stone. Likewise, to prevent the earth from escaping sideways, it should be inclosed within solid walls.

Furthermore, as the earth filling is put in place it must be carefully settled. Occasionally an attempt is made to settle earth by pumping water on it as it is put in position but this has not been proved to be perfectly satisfactory. Indeed, no method of packing an earth fill seems to be as safe and satisfactory as to place it in layers from 3 to 4 inches thick and then to ram each layer thoroughly before putting the next upon it.

MASONRY AND CONCRETE.

Although the sand parapet is supposed to constitute the main resistance to an enemy's projectiles, yet it can not be used to the entire exclusion of masonry. There are places, even on the exterior of a battery, where vertical walls are required, and the rooms, galleries, etc., must have walls and ceilings. Furthermore, the floors must be smooth so that the ammunition trucks may be rolled thereon. In all such places masonry or concrete is required.

Experience has shown that where the muzzle of a gun extends over earth or grass and the gun is fired a considerable amount of earth and dust is blown away by the discharge of the gun and continuous firing makes quite a crater. To avoid this it has become customary to place immediately under the muzzle of the gun and for some distance to the front, a concrete blast apron made so thick and so strong as not to be destroyed by the blast.

About the only masonry now used in emplacement construction is concrete, and this concrete does not differ in its essential qualities from the concrete in use in ordinary commercial life.

In the early nineties when the construction of the modern concrete emplacements was begun, Portland cement was not manufactured in this country and could be obtained only from abroad and at a high price. There were, however, a number of brands of so-called natural or Rosendale cement made in America that could be purchased much more cheaply. Consequently, for reasons of economy, Rosendale cement was used, at least in most of the gun emplacements constructed on the Atlantic coast. Shortly thereafter, however, there was a rapid development in the Portland cement industry in this country, and since about the time of the Spanish War the only cement used has been Portland.

The specifications which have been used in the purchase of this cement have been the standard of the Engineer Department in all its work and no further remarks are necessary concerning them.

The aggregate used in concrete has in general been broken stone, though gravel is equally good when available and cheaper than stone.

As a general rule, the sand which has been used has been that available in the immediate vicinity. A large proportion of our emplacements have been located on sand beaches, so that sand has been very plentiful. Frequently this sand has not been very sharp and has not made as good concrete as other sand, yet on account of its abundance it has been more economical to use this sand even with an increased percentage of cement than to purchase other and better sand and use the normal proportion of cement.

Our modern emplacements contain a great many granolithic walks and wide ceilings supported by reinforced concrete slabs. In all such places very strong concrete is necessary and consequently the custom has arisen of using in certain cases two qualities of sand, the better quality for granolithic and slab work, and the poorer quality where mere mass concrete only is desired. This was done to a great extent in the Hawaiian Islands. The batteries there were, as a rule, built where there was an abundance of coral sand; that is, sand formed by disintegrated coral. The concrete made with this sand was not strong enough for slab work, but it could be used for mass work. For slabs or granolithic work, however, where strength was desired, the sand which was used was obtained by pulverizing lava rock. This lava sand was quite expensive, costing from $2 to $2.50 per yard, delivered at the site of the battery, whereas the coral sand being plentiful in the vicinity cost almost nothing.

The proportions of the various ingredients of concrete are determined in the same way as in the concrete used for civil engineering work. Where great strength is necessary, proportions as high as 1, 2½, and 5 are used, in some cases even 1, 2, 4. In mass concrete 1, 3, 6, or even 1, 3½, 7 are frequently used.

Mixing and Placing of Concrete.

In the first concrete emplacements built but little care seems to have been taken in the mixing and ramming of the concrete. It seems to have been thought at that time that about all that was needed was mass and that ramming was not very necessary to make the concrete strong. Occasionally the concrete was dumped in by the skipful, the surface being then tamped a little, but the effect of this tamping did not, of course, extend very far down into the mass. Sometimes it was customary to dump the skips while moving, which would thus scatter the cement considerably, and wherever the concrete fell it was tamped to some extent.

At this time it was customary to mix the concrete extremely dry, laboratory experiments having shown that dry concrete properly rammed was stronger than if mixed wet. This was all well enough for laboratory work, but it did not do in practice, because it was impossible to insure that the concrete would be rammed well enough to get the little water that it contained completely distributed through it.

The consequence was that although mass was obtained and apparently the necessary strength, the concrete prepared in this way was as a rule quite porous, in some cases about as porous as a sieve. Water would seep readily through it and much difficulty was later found in keeping this seep water out of the rooms and magazines. This subject will be discussed later in the Chapter on Dryness, etc.

Finding that mixing the concrete with more water made it easier to ram, the next tendency was to make the concrete too wet—so wet in fact that it could not be rammed but could be merely puddled.

The opinion of the engineering world is still divided as to what is the best amount of water to use in mixing concrete and as to the best method of placing it, but as the requirements of concrete for fortification purposes are essentially the same as those for other construction purposes, the matter will not be further discussed here.

Construction Plant.

It is not necessary to go into this subject since the problem is the same as has to be solved in connection with other concrete construction.

Planes of Weakness.

When concrete emplacement construction was first begun it seems to have been the idea that the emplacement should be made as monolithic as possible. To accomplish this, the work was sometimes run continuously day and night, and when day work only was used, it was customary upon resuming work after the overnight's delay to carefully brush off and wash off the surface of the old concrete, to dampen this surface, and then apply to it a layer of mortar before beginning the deposit of the new concrete. It was thought that by this means the new concrete would be bonded to the old and that an essentially monolithic condition would be obtained. It has been found, however, that new concrete does not bond well to old, and that the monolithic character desired was not obtained.

It was soon discovered, moreover, that the irregular settlement which appears inevitable, and the irregular expansions and contractions due to temperature changes, cause cracks to occur in a large mass of concrete. If left to chance these cracks may occur at the worst places possible, and consequently, since it is known that they will occur in any case, it is desirable to insure that when they do occur they will occur at places where no harm can be done.

For this reason there are usually left in emplacement construction what are called "planes of weakness." The method of creating one of these planes of weakness is simply to build the separate parts independently; that is, one section is built up against a wall of smooth framework placed along the desired plane of weakness. When this section is completed, the framing is torn down and the next section is then built. These sections, built separately in this manner, do not bond. In the early days layers of building paper would be placed between them, but this has been found not to be necessary.

The gun block of a large emplacement is built so as to be separated from all the concrete work around it by planes of weakness. This gun block is built solid and heavy. It supports the gun and carriage which are both heavy. To the gun block is transmitted directly the shock of the discharge and consequently it is much more liable to settle than the portions around it. By surrounding it with planes of weakness it is left so that it can settle independently and without causing cracks in the neighboring concrete. Similarly the heavy parapet in front of the loading platform is usually separated from the mass behind it by planes of weakness and is sometimes divided up into lengths by planes of weakness extending from front to rear through the parapet. In the more modern type of emplacements, when the magazines are surrounded by air spaces, planes of weakness are frequently located so that they pass along these air spaces. (See Plate XXV.)

Mimeograph No. 8 published in 1896 says:

> Cracks having appeared at more than one locality it seems expedient to call the special attention of officers of the Corps of Engineers engaged in fortification work to the necessity of providing for planes of weakness between portions of the concrete masses which differ in dimensions and weight, or which rest on different foundation strata. Such planes of weakness should be provided at all places where cracks are liable to form from settlement or from unequal expansion and contraction. Particular care should be given to the gun platform. As designed it possesses ample strength where it can rest on a good foundation. Where a firm subbase is not found, provision should be made for strengthening it. It is particularly necessary that it should rest on a uniform stratum. No portion of it should be joined to or rest on any portion of the parapet mass.

SURFACE FINISH OF CONCRETE.

In building the early emplacements, especially where Rosendale cement was used, it was customary to use very rough lumber for the forms. After these forms were taken away the surface of the concrete would of course be very rough and irregular, and in order to make it look better it was plastered over and given a nice finish.

For a while the coarse concrete finished in this manner looked very well, but it was soon found that the plaster coat would not as a rule stand the effect of frost, and would peel off nearly everywhere. With Portland cement concrete this peeling off does not occur so frequently, but it has happened at times and where it has peeled off the effects are uglier than if it had never been put on at all.

For the above reasons the practice is becoming more and more common of making the concrete framing of dressed boards carefully planed, finished on all four sides, and neatly put together with all joints exactly vertical or exactly horizontal. With care in placing the concrete, or by making the proportions of the aggregate a little less in the portion to be placed next to the boards, or by puddling the concrete with the end of a spade as it is placed against the framing, that portion against the boards is made very smooth and when the framing is removed the surface is unbroken and shows off very well the grain of the wood. Under such conditions no plaster coat is necessary.

In this connection it may be noted that as a rule the wetter concrete is mixed, the easier it is to get a nice finish. However, where the concrete is to be mixed very wet, great care must be taken in building the framing, and the thinnest joints possible must be used. When wetted, of course, the boards swell slightly and the joints become waterproof. Otherwise the surplus water in the concrete may leak out, carrying with it much of the cement and thus weakening the concrete in addition to interfering with its appearance.

Granolithic Finish.

In finishing a nearly smooth horizontal surface which is to be used as a pavement or walkway, the same care is necessary as in finishing any granolithic walk. The concrete near the surface is mixed quite rich in cement and the surface layer contains none of the larger aggregate. As soon as placed, the concrete is pressed down to squeeze out the water and as it begins to get its set it is carefully rubbed down with a wooden float. Strictly horizontal surfaces should, in general, be avoided, drainage slopes being provided wherever possible. This, however, is a matter which will be discussed more in detail in the chapter on Dryness, etc.

It is usual in laying pavements to do the work in alternate blocks so as to insure that any cracks that may subsequently occur will occur along the joints and will not mar the appearance of the pavement.

Blast Apron.

In finishing the concrete apron immediately in front of a gun, great care must be taken to insure that the concrete shall not be cracked up by the effect of the blast and subsequently be blown away. In the earlier batteries it was customary to finish the concrete up to within from 6 to 8 inches of its final level and then later to lay a sort of pavement upon it. Such construction, however, was quickly cracked and blown away, this thin layer not being properly bonded to the concrete below. With the increasing power of guns, the difficulty of preparing a proper concrete apron has also increased, and the method now considered best is to lay the last 4 or 5 feet or so of the parapet as nearly monolithic as possible. The regular work of placing the concrete is stopped when within 4 or 5 feet of the final level. Arrangements are then made so that the remaining concrete can be put in place without interruption, and this is done as rapidly as possible and is continued completely to the surface itself, which is smoothed off and floated down without delay and before the concrete below it can have reached its final set.

In the older batteries where Rosendale cement was used it was practically impossible to make the concrete in front of the guns sufficiently strong to withstand the blast, and to overcome this weakness resort was occasionally had to substituting Portland cement in this section of an emplacement. Occasionally, also, the attempt was made to use thick metal blast plates held down by long bolts, but these were found to be unsatisfactory. Fortunately, however, it was discovered that properly prepared Portland cement concrete is sufficiently strong to withstand the blast effects, and where put in as above described the blast aprons have been found to be satisfactorily durable.

Corners and Edges.

Though concrete is strong and generally a serviceable material for battery constructions salient corners of it, such as door jambs, the corners at turns in corridors, etc., are apt to be chipped off by things accidentally striking them. Consequently, the custom has grown up of rounding off or beveling all such corners. The rounding off requires a special form of molding. The beveling can be easily arranged by inserting in the corner of the framing a triangular piece of wood made by splitting a square piece of scantling along the diagonal of its cross section.

Some officers in order to make their work look better build such exposed corners of pressed brick and sometimes they insert stone lintels, etc. These details, although they add to the appearance of the battery, are believed to be unnecessary and unduly expensive.

Tinting Concrete Surfaces.

In connection with the finish of concrete work there is another subject frequently of great importance. Concrete when hard and dry is nearly white and the glare from such a surface when exposed to sunlight, especially in the Tropics, is very disagreeable. In order to avoid this, it is desirable if possible to darken this surface.

One method of doing this is by mixing lampblack in the concrete that is to be used near the surface. Powdered blue stone or red stone is also frequently used for this purpose. When first completed, the granolithic surfaces made with powdered stone or lampblack are much darker than concrete in which some darkening substance has not been used. It has been found, however, that all such concrete quickly wears lighter.

Frequently, too, the same end has been accomplished by applying to the surface when completed a water-mixed paint. A dull green was used for this in connection with the Panama fortifications and has proved very successful not only on pavements but also on vertical walls.

For the vertical concrete walls around the loading platform some form of darkening also is desirable. One method used for this purpose was to apply to these walls a cement wash containing lampblack. Since lampblack itself is not soluble in water, it is usually dissolved in wood alcohol or some other cheap solvent, and is then added to the water used in mixing up the cement wash. It is applied by means of a brush. Walls when freshly painted this way are very nice looking, but unfortunately the lampblack has a tendency to wear away irregularly and the walls soon become splotchy.

Another method of darkening the walls has been the application of boiled linseed oil applied quite frequently in coats until the wall has absorbed enough oil to give it a proper hue. Sometimes a little pigment has been mixed up with this linseed oil. This linseed-oil coat is supposed to have the additional quality of making the wall waterproof, but it has been found in a number of cases that the concrete has been injured by the oil.

The conditions as to excessive glare from the concrete surfaces are quite reversed in the interior of batteries, where as much illumination as possible is needed, since the personnel have to go frequently back and forth from outside to inside. Consequently, the better the light reflecting qualities of the interior paving and walls, the more generally will light be diffused within the interior of the battery and the better will be the general illumination of the interior. Concrete walls are of course not perfectly white, and it improves the general diffusion of light within an emplacement to paint the walls and ceilings white. Several varieties of paint have been found suitable for the purpose and some of the formulas for these have been published in mimeographs or circulars.

The white paint on the walls and ceilings should, of course, be restricted to concrete surfaces. Paint should never be applied to tile surfaces or the surface of porous bricks, for the paint fills up the pores of the tiles or brick and thus prevents them from accomplishing their proper function. (See Chapter on Dryness, etc.)

Effect of Oil on Concrete.

In connection with the concrete work, not only of emplacements, but even more especially of some of the smaller buildings, the effect which oils may have on the concrete must be given consideration. This matter should likewise not be overlooked in connection with concrete used in civilian construction.

If, after concrete has become thoroughly set and hard, oil be applied to it or be allowed to fall upon it no immediate effect is seen, except possibly a stain or a change in color. Experience has shown, however, that certain forms of oil applied to concrete have a tendency to cause a slow disintegration, and the conditions which cause this disintegration have as yet not been thoroughly determined, either as to the varieties of oil which will cause this action or as to the amount which has to be present or the circumstances under which it has to be applied.

Some years ago tests were made by the department upon neat cement briquettes which had been previously tested in a machine and which had been found sufficiently strong to withstand tensile strains of more than 800 pounds per square inch. When several months old, some of these briquettes were painted with coatings of different kinds of oil and some of them were placed in saucers containing different varieties of oil. For a considerable time no change was noted, then there developed in certain of the briquettes a sort of crumbling or disintegration and in some six months or so a few of the briquettes had been disintegrated into what might be called a mass of powder saturated with oil. These experiments were somewhat contradictory as to the kinds of oil which produced this effect, there being at least one case where two briquettes, painted apparently under the same conditions and with the same kind of oil, were acted upon very differently, one being completely disintegrated and the other being almost uninjured.

This matter is of considerable importance when for any reason it is desired to paint a concrete surface, since the oil used in the paint may affect the integrity of the concrete. Plain boiled linseed oil, applied to a monolithic concrete surface, darkens the surface and apparently has no tendency to cause disintegration, but, if applied to a plaster coat placed over a concrete surface, it seems to accelerate the rapidity with which the plaster will peel off, the oil working its way through the plaster coat and dissolving the imperfect bond between the plaster and the concrete surface upon which it was placed.

Cases have also happened where the oil drippings from a gun carriage have caused a softening or disintegration of the concrete paving below. Often, however, no such effect has been noticed. So, whether the cases where disintegration has occurred have been due to the peculiarities of the cement used, to the particular brand of oil, or to some special peculiarities of the case, has not yet been determined.

However, there is one thing in connection with the effect of oil on concrete that would appear to be certain, and that is that the action may be extremely slow, and that when a particular brand of oil has been applied to a concrete surface and nothing apparently has happened for some time the conclusion should not hastily be jumped at that no harm has been done.

As far as the knowledge of the writer of these notes goes, the effect of oil on concrete and, for that matter, the effect of sea water on concrete are both problems which have not yet been thoroughly solved. That they may have been solved is not improbable, and that if they have not yet been, they will be before long is practically certain, but until something much more definite has been learned about them it is thought that the constructing officers should exercise considerable care in permitting oil to be applied to concrete. For the present, therefore, it is believed to be safer to use water-mixed paints instead of oil paints wherever it is necessary to paint a concrete surface.

Roof Construction.

In the first designs for emplacements, it seemed to be considered necessary to make all the ceilings full center arches, and all the batteries begun in the very early nineties were built this way. Thus, the first mortar batteries, built at the Presidio, San Francisco, and at Sandy Hook, New York Harbor, and the earlier gun batteries, built at Fort Monroe, are of this type. (See Pls. XIII and XXVII.)

When the rooms and galleries were quite narrow these full center arches did not place the ceilings very high, but when it was found that the width of these rooms was not sufficient and that wider rooms had to be provided the lost vertical space became a serious obstacle, and to avoid this the batteries were designed with flat roofs supported by **I** beams extending all the way across the room from wall to wall.

This type of construction seems to have been introduced about 1895. Comparatively large beams were used. Where a corridor or passageway was about 4 feet wide, a 4-inch beam was used. In rooms 12 and 14 feet wide, 10-inch beams were provided, and so on up. The beams, of course, were made long enough to extend at least a foot into each side wall and, in order to distribute the pressure which they would bring to bear upon the walls supporting them, special plates of cast iron were inserted under them. This latter provision, however, was done away with as it was found to be unnecessary.

These beams were, in general, placed parallel and 2 feet apart, center to center, and the portions of the ceiling between each two beams were made in the shape of a flat segmental arch. Generally the concrete in this arch was exposed to sight, but in a few places the corrugated sheet-iron arches provided to hold up the concrete as it was put in place were left after the concrete set.

It was shortly found that the framings for these small arches were difficult to put into position and were expensive. The experiment was therefore tried of doing away with them and making the ceiling between the beams perfectly flat. In a report issued by the Board of Engineers in July, 1896, and published as a mimeograph, it is said:

> The ceilings of magazines should be flat. Arches between ceiling beams are unnecessary.

Of course, in this form of roof construction the lower flanges of the ceiling beams were exposed to view, and incidentally to the moist air of the magazines. To protect them from rust they were painted, but it was soon found that it was difficult to keep them so thoroughly painted as to prevent them from rusting.

The next step, therefore, in ceiling construction was to embed these beams in the ceiling about 2 inches above the exposed surface of the ceiling.

This was accomplished by building the walls about 2 inches above the ceiling level before placing the beams. Incidentally, also, before any beam was put in place the framing over which it was to go was covered with a layer of concrete, some 2 or 3 inches in thickness, from which all large stones had been removed. The beams were then put in place and the concrete dumped between them, binding the whole mass together so that when the framing was removed the beams were hidden and were not seen.

The type of construction mentioned above, with the beams either hidden or exposed, was continued for a considerable time; in fact, until the invention of the different systems of reinforcing concrete by deformed steel bars. In 1903 the Board of Engineers recommended that thereafter this latter type of construction be utilized in emplacements and the mimeographs publishing the plans of the 1903 types of 12-inch emplacements showed, in addition to other things, the sizes and locations of the reinforcing bars necessary.

Steel Reinforcement.

In designing the reinforcing for the concrete work used in emplacements it has been considered necessary to adopt rules as to the amount of reinforcement required which differ considerably from those used in designing the concrete slabs ordinarily used in the construction of buildings intended for civil purposes.

In the latter it is considered that when a concrete ceiling slab is once put into position it will remain indefinitely, and consequently the entire thickness of the concrete, except possibly a very small allowance for wear at the top, can be counted on as assisting to bear the stresses that will come on the compression side of the slab.

In designing emplacements, however, especially the wide roof spans over the magazine spaces, it is to be assumed that the upper portion of the mass of concrete is subject to the destructive effects of projectiles that may strike it or may penetrate it slightly and then explode. Furthermore, as will be mentioned in the chapter on Dryness, it is frequently necessary to place in the interior of this mass an intermediate waterproof surface. For these two reasons, and in order to be on the side of safety, it is usual in designing the reinforced concrete roofs over magazines to assume that only so much of the thickness of the concrete as is absolutely essential is acting to help support the weight, and that all the concrete above this minimum thickness is to be considered as in no way adding to the strength of the beam but as acting merely as so much additional dead weight to be supported. For instance, in one case where the roof span was 27 feet and the thickness of the concrete 12 feet, it was assumed that the total weight to be supported would approximate 1,800 pounds per square foot of ceiling surface, and that therefore the weight on the portion of the slab 1 foot wide and extending entirely across the span would be approximately 50,000 pounds. A beam 1 foot wide and 27 feet long would have to be about 36 inches deep, assuming the amount of steel reinforcement as slightly less than 1 per cent of the cross section. The reinforcement was therefore designed as if the total depth of the beam was 36 inches and the weight of all the rest of the concrete was considered as being supported by this slab 36 inches thick. This permitted the intermediate waterproof surface to be so designed as to come just above this 36 inches of the ceiling surface.

Apparently this is somewhat unduly expensive in the matter of steel, because it is evident that a good deal of the concrete above this slab will actually act in compression to help support the load, and the strain on the steel will not be as great as that computed. However, there is always the possibility that a projectile or a bomb may penetrate through the earth blanket and actually enter the concrete a short distance and there explode, not only shattering the concrete to a considerable extent but actually bringing a sudden blow upon the supporting slab.

The rule above mentioned is ordinarily applied only to the wide ceiling slabs over the magazines and galleries in the traverse, to the ceiling slabs of the rooms under the loading platform, and to the ceilings of corridors, or galleries, or shell recesses opening through the parapet in front of the loading platform. In other cases of reinforcing, such as the cantilever stairways and platforms, and in the short lintels over doors and windows where there are no intermediate waterproof surfaces to interfere, the reinforcing is designed according to the rules usual in civil construction.

The reinforcement of concrete columns is usually made of plain steel bars and not of deformed bars, and these bars are usually bonded or wired together at intervals to prevent them from spreading.

FOUNDATIONS.

So far as its foundations are concerned, a gun emplacement is nothing more or less than a masonry structure, and exactly the same precautions should be applied in constructing the foundation of a gun emplacement as would be considered necessary in constructing the foundation of any heavy masonry structure, whatever the purpose for which it is intended.

Unfortunately, the location of a gun battery is fixed by other considerations than stability of foundations, and the preparation of a satisfactory foundation is frequently a serious engineering problem.

Another consideration which increases the foundation difficulty is that the weight of a gun emplacement is quite unequally distributed. Thus the concrete parapet is solid. The gun platforms are much lower than the parapet and it is evident the weight of the gun and carriage is much less than if the gun block were extended upward in solid concrete to the level of the crest of the parapet. Farther to the rear is the loading platform, and in large emplacements, rooms or other voids are usually placed under the loading platform so that the weight per square foot of foundation under the loading platform is much less than under the gun block, and the weight per square foot under the gun block is much less than under the parapet.

Similarly, in the traverses between the guns, the weight is unequally distributed. Immediately in front of the magazines the concrete is built solid in order to insure protection to the ammunition. The magazine spaces are, of course, empty but are covered by a thick concrete roof. Farther to the rear there are the hoist rooms and still farther rooms or corridors below and open corridors above.

Consequently, both near the guns and through the traverses, emplacements are much heavier per square foot of area in front than in the rear. If the emplacements are built upon ground that is yielding or which rests upon a compressible stratum, it is but natural to expect that the settlement will be greater in front than in rear, and that, taken as a whole, there will be a tendency for the emplacement to tip forward.

This has actually occured in many cases, and has not infrequently gone so far as to interfere with the drainage system of the battery. It is the usual custom to give loading platforms a slight slope to the rear to encourage rain water to run in that direction. The drainage slopes given have usually been from about 1 to 2 per cent, and whenever the tipping due to irregular settlement has exceeded this the drainage has been reversed and the water, instead of running off the loading platform to the rear, has had a tendency to run forward toward the foot of the parapet.

In a few fortification sites, especially those on the New England coast and on the Pacific coast, the soil has been found to be rocky and sufficiently strong to stand any reasonable weight, and trouble has not been experienced from irregular settling. Along the middle Atlantic, South Atlantic, and Gulf coasts, however, no rock or absolutely stable foundations are found, and, in general, emplacements have been located upon sandy coasts where the normal level of the site is only from 5 to 15 feet above tide level. Where this sand rests upon rock, packed gravel, or hardpan, it is not difficult to prepare a suitable foundation. Sand itself, when confined, is incompressible, and all that it is usually necessary to do under the conditions mentioned is to excavate the sand down to about the level of ground water, and then to begin to lay the concrete upon the saturated sand without other precautions than spreading the foundations of the walls. This is the ordinary method of construction and has in general worked well. Where undue settlement has occurred it has ordinarily been found to have been due to strata of mud or other compressible material underlying the sand at no great depth.

In a few places it has been known that the sand is of comparatively recent formation or that it contains considerable mud or there may be reasons to believe that some thin mud strata of unknown compressibility underlie the sand. In such cases resort has frequently been had to covering the entire area of the battery by a reinforced concrete slab, made sufficiently strong to take up the weight of the structure and transmit it fairly uniformly to the foundation. In the early constructions of this character the steel reinforcement was made by inserting heavy **I** beams in the foundation. First a tier of **I** beams would be placed with the beams from 2 to 3 foot centers. Immediately above this would be placed another tier at right angles. In the latest structures, instead of using **I** beams in this manner steel reinforcing bars have been used, so placed and so bent with regard to shear as to distribute the weight of the structure uniformly to the foundation.

Where it is known that the substrata can not be relied upon to hold up the heavy weights, foundation piles must be driven, and these piles should be so distributed as to make the weight to be borne by each approximately the same. Where the piles are driven so as to be always submerged ordinary pine piles will suffice. Where they are to extend above the ground-water level either creosoted piles or preferably concrete piles should be used.

In a few cases, especially in the Tropics, considerable difficulty has been met with in connection with the foundations of batteries. Thus, under one of the forts in the Hawaiian Islands it was learned by making borings and the sinking of test pits that for a depth of at least 60 feet the underlying earth consisted of disintegrated coral, fine coral sand, and alluvial mud mixed most irregularly. Scattered irregularly through this mass were large coral bowlders with many fragments of so-called finger coral; that is, fragments from 2 to 12 inches long and from about one-quarter of an inch to 2 inches in diameter.

In the preliminary drilling into this mass of earth, the pipe used to make the boring sank with extreme ease, and it was decided to build the batteries upon long concrete piles. When, however, the attempt was made to drive these long piles considerable difficulty was experienced. Occasionally the piles would run up against a lump of coral, which either had to be pushed out of the way or penetrated. After the battery was completed, very slight and fairly regular settlement was experienced except at one place, and that was under one of the gun blocks where, strange to say, the piles were more difficult to drive than anywhere else.

For a smaller battery the gun blocks were founded on piles, which held perfectly. The magazine traverse, however, was built upon a reinforced concrete slab. It was figured that this slab might settle about 12 inches, and it was hoped it would settle fairly uniformly. In fact, it settled about 10 inches in the rear and slightly less than 13 inches forward. Since the tilt thus caused was not sufficient to interfere with the drainage system no trouble has been caused.

At another one of the Hawaiian forts it was found that the site of a battery was underlaid at a distance of about 20 to 30 feet by a thick coral ledge. The portions of the battery which were considered important—that is, the gun blocks, magazines, etc.—were all founded on piles driven through the soft strata to the coral ledge, and no material settling was experienced. The parapets were built without piles, and when raised nearly to full height work was stopped on them and they were allowed considerable time to settle. When it was found that settlement had about ceased, the parapets were then brought up to slightly more than full height, a small allowance being made for subsequent settlement.

In the Panama batteries, except in one locality, there was no doubt about the capability of the foundations to support the battery. The exception was an island where the soil consisted of a soft mud underlaid by coral. Piles were driven through the mud to the coral and the batteries built upon the piles. In the case of two batteries no material settlement occurred. In the third and largest battery, however, the weight apparently proved too great for the coral stratum, which seems to have broken through, permitting the battery to settle considerably and irregularly.

The problem of foundations is important and is purely a local one, dependent upon condition of the site. The constructing engineer should therefore make a careful investigation and study of the local conditions and do the best he can under the circumstances. Frequently the best that can be done is to divide the battery by planes of weakness into several sections, which may thus settle separately and independently; to then build the battery nearly to the top, to permit the settlement to occur, and subsequently to put the finishing touches to the battery.

Encroachments by the Sea.

Experience has shown that the sand beaches along most of our seashores on the Middle, South Atlantic, and Gulf coasts are constantly making or cutting away. Apparently this action is somewhat periodic; that is, where a beach is cut away at one time it is apt to be subsequently built up again, and, on the other hand, a beach built up far in advance of its normal location may be cut away again. In some cases the beaches are built up by storms and cut away under normal conditions of wave and sea, and in others they are cut away during storms and are subsequently built up to their normal positions between storms.

Occasions have arisen where it has become necessary to build a battery so close to one of these fluctuating beaches as to be within possible danger, at least temporarily, from an extreme case of erosion. It is essential in such cases that the battery should not be allowed to be undermined. If it is built upon piles, the sand can be temporarily washed from under it without injuring the concrete work of the battery. Subsequently a change of conditions may wash the sand back under the battery and build up the beach in front of it. Of course, wherever this occurs the sand parapet is lost and has to be replaced.

For these reasons, where batteries have been placed close to a beach and there seems to be a tendency to possible encroachment by the sea it has been customary to build sea walls or groins along the beach in front of the batteries and to fill up between the sea wall and the battery to at least the level of extreme high tide. Sometimes where these extreme high tides occur only very infrequently the sand flat has been left a few feet below such level and the lower 2 or 3 feet of the parapet has been revetted with rock.

The place where the greatest difficulty of this character has been experienced is at Galveston, where the natural level of the sand beach is quite low. Within the last few decades, however, this vicinity has been visited by severe tropical hurricanes accompanied by high water, rising to as much as 15 feet above ordinary low tide. The first storm of this character washed away all the sand parapets and undermined and destroyed the concrete work of the batteries not built upon piles. Where the concrete work was founded upon piles it was not injured, and the sand could, of course, be replaced. Subsequently a strong sea wall was built in front of one of these forts. The question of building similar walls in front of the other has frequently been discussed, but up to the present has been considered as not justifiable on account of the high cost.

STEEL AND IRON.

Steel and iron are used in fortification construction and equipment:

In ordinary structural steelwork, such as towers, either fixed or disappearing, and in roof trusses, etc.

As I beams for reinforcing ceilings or fortification slabs.

In columns for supporting ceilings or the rails of bridge cranes.

For reinforcing concrete, in the form of simple or deformed steel bars, wire mesh, or expanded metal.

As metal laths used in plastered walls.

As rails for railroads, tramways, or trolley tracks.

As piles for supporting wharves.

As pipes for water supply, sewage disposal, or speaking tubes.

As stairways or ladders, either in emplacement construction or in connection with towers.

As handrails for platforms, stairways, and in other dangerous places.

In doors and windows, either solid or grating, and in manhole and ventilator frames and covers.

In hold-down bolts for the base rings of gun carriages.

In the curbing around the top of gun wells.

In ringbolts for maneuvering purposes.

In machinery such as engines, generating sets, trolleys, ammunition hoists, and the receiving and delivery tables for the same, or in service and storage tables, etc.

In electrical fittings.

As tools.

In many miscellaneous ways.

In general, the uses of iron and steel for the purposes mentioned do not differ from similar uses in commercial life, and the iron and steel work for these uses is usually bought under the standard commercial specifications. In the following cases only do any special remarks appear to be needed:

For use in reinforcing concrete ceiling slabs and foundations deformed steel bars are in general preferred to plain bars, and it seems to be considered advisable to use several smaller bars rather than a few larger bars. As a rule the largest bar used is the 1½-inch, although 1¾-inch are occasionally found in special places. Larger bars are apparently never used. For reinforcing columns, plain bars with occasional bands to prevent spreading seem to be preferred. Wire mesh and expanded metal are much used for reinforcing thin concrete walls, and, along with metal lathing, as the support for plastered or stucco walls.

In a number of early emplacements the handrails used were too small. Not only did they not look well, but they bent too easily. Consequently, it is now the custom not to use handrails smaller than 3 inches. The handrails themselves and all the different kinds of fittings are on the market and are described in the manufacturers' catalogues.

Hold-down bolts for the base rings of gun carriages have to be specially made and under special specifications. This matter will be more fully discussed in the portion of Chapter VII relating to the subject.

In the early days it was the custom to permit district officers to purchase machinery and electrical fittings through their own district offices, but this led to so much dissimilarity between districts that all this work was concentrated, first, in a single district office and later in the main Engineer Depot. Generator sets, ammunition hoists, electrical fittings, etc., are all now standardized and can be obtained by district officers through the Office of the Chief of Engineers or the Engineer Depot.

TIMBER.

Wood and timber are used in fortification construction:

For concrete framing.

For building various kinds of houses.

For ceilings, floors, and doors of buildings built otherwise of fireproof material.

For the interior fittings of buildings, such as benches, stools, chairs, tables, etc.

For stairways in fortifications.

For building wharves, etc.

In the early days it was customary to use only rough lumber for concrete framing. This, however, required the finishing of all concrete walls after the framing was removed. To avoid this the custom was adopted of using smooth, dressed lumber for concrete framing, so that no subsequent plastering of the walls was necessary. As a rule, light, thin lumber should not be used, the best results having been obtained by making the surfacing of tongued and grooved umber, nearly 2 inches thick, and having faces about 6 inches wide. The studding also must be fairly large so as not to bend perceptibly between braces.

For many years it was customary to build of timber many of the important fortification buildings, such as range stations, plotting rooms, switchboard rooms, mining casemates, searchlight stations, etc. Where these structures were isolated, the fire risk was but slight, but when it became customary to group the buildings the risk became greater, for a fire in one building might destroy others also. Consequently, buildings of this class are now, as a rule, built of fireproof or fire-resisting material. Timber, however, is still used for the temporary offices and storerooms used by the Engineer Department during construction, and for small temporary or peace-time structures around emplacements, also occasionally for dormitories and other nonessential buildings, so located that their destruction would not endanger other buildings or interfere with the defense.

In casemates, switchboard houses, etc., even when otherwise fireproof, the ceilings and floors of rooms to contain much wiring are frequently made of timber so as to facilitate the attachment of wires. The doors, doorframes, and window frames of such buildings, as well as of other fire-proof buildings, are likewise frequently made of wood.

Benches, stools, chairs, tables, etc., are required in nearly all classes of structures, and for the comfort of the personnel these are made of wood.

In a number of cases wooden stairways have been built so as to permit easy access to the crests of parapets of emplacements during drills and target practice. These being considered originally as temporary, or, at least, peace-time constructions, were frequently built of wood. These wooden stairways, of course, rotted away in time and, as a rule, have been replaced by concrete stairs.

Most of the torpedo wharves heretofore built have been of timber, as is usual in civil life. In a few cases, though, reinforced concrete wharves are now being substituted.

GLASS.

Window glass used around fortifications should, as a rule, be of extra thickness and of extra good quality. Where blast effects are to be feared wire glass should be used.

TILES.

The structural tiles ordinarily used in civil constructions are usually burnt quite hard to give them strength and are left quite rough and are fitted with small dovetailed grooves to catch hold of the mortar. In emplacement construction the tiles are desired principally on account of their porosity and water-absorbing qualities. Medium burned tiles are, therefore, to be preferred, and since the tiles are to be left in view in the completed work one face, at least, of each tile should be left fairly even and smooth.

The tile ducts used for the underground installations of electric wires and cables need be only of the usual commercial quality.

CHAPTER V.

AMMUNITION SUPPLY, STORAGE, AND SERVICE.

The term "ammunition storage" explains itself. "Ammunition supply" includes manufacturing the ammunition, transporting it to the vicinity of the battery, moving it into and storing it in the magazine. "Ammunition service" is the term applied to the movement of ammunition from the magazine to the gun.

The Engineer Department is interested in two main movements of the ammunition: First, in ammunition supply, the handling of the ammunition from the point in the vicinity of the battery where it is delivered by the Quartermaster Department to its storage place in the magazine; second, in ammunition service, the movement of the ammunition from the magazine to the gun.

The first of these movements of ammunition, bringing it to the magazine, is a process properly performed in time of peace or, at least, before the particular fort becomes actually engaged. Ordinarily, therefore, no special haste is necessary in thus moving the ammunition and usually there is an ample number of men available. Nevertheless, all batteries should be so designed that all the handling of ammunition necessary in getting it into and storing it in the magazines can be done easily and without undue physical demands upon the personnel. It is probable, of course, that after war is begun additional ammunition may have to be sent to certain batteries, but the handling of this ammunition, at least in the immediate vicinity of the batteries, can evidently not be done during an engagement. It must, therefore, be handled between engagements when no very great haste should be necessary.

The movement of ammunition in ammunition service must be very rapid and it is the duty of the Engineer Department to so design its emplacements that each and every step of the ammunition service may be performed with such speed that the ammunition can be carried to the breech of the gun at least as rapidly as it can be loaded into the gun and fired; and so that the rate of fire which can be obtained from the gun shall be limited by considerations other than the functioning of the portion of the ammunition service for which the Engineer Department is responsible.

In addition to these two main movements of ammunition there are two others in which the Engineer Department may be interested: First, such movement as may be necessary from time to time during storage, such as rearranging the ammunition so as to place what has not yet been used where it can be more readily handled when it becomes necessary to serve it to the guns; second, replacing in the magazine ammunition which had been carried to the gun, but which had not been fired. This is very frequently necessary in drill and may be necessary in time of war, at the end of an action.

In providing means for handling ammunition, the Engineer Department is merely called upon to solve a particular case of what is probably the most common problem that is presented to mechanical engineers—the movement of heavy weights. Furthermore, neither in the total amount of material to be moved nor in the size of the largest individual pieces do the difficulties to be met with in handling ammunition begin to compare with those which are successfully overcome daily in commercial life. Nevertheless, there are certain conditions connected with the handling of ammunition, especially in serving it to the gun, that make the problem somewhat unique.

The appliances provided for the handling of ammunition in ammunition service must be absolutely and thoroughly reliable. They must be such as to require no time for adjustment when called upon for use. They must be capable of being left absolutely without attention for a considerable time, many weeks and perhaps months, and yet must be instantaneously available. They must be strong, capable of standing considerable abuse, and of being operated by untrained or poorly trained men. In fact, they should be so simple in operation that practically no training is required, yet when called upon for use they must be capable of handling the ammunition rapidly and under conditions where even seconds of time are important. In many cases they are installed in locations where they are subject to extreme dampness and other corrosive agencies and yet must not be injured by these agencies. They must be used frequently under conditions where the men are cramped for space and where the illumination is extremely poor. All these conditions must be given consideration by the fortification engineer, who must, in spite of them, provide simple, fool-proof, thoroughly reliable, and sufficiently rapid means of handling the ammunition.

The means which must be provided for moving ammunition and, for that matter, any other class of articles, depend, of course, upon the weight and bulk of the pieces to be moved.

For guns not larger than 5-inch, the projectiles and the powder are ordinarily stored and transported to the gun in the form of complete cartridges, put up in metallic cases, similar, except as to size, to the metallic cartridges used in the Infantry rifle. These complete cartridges weigh so little that they can be easily transported by hand and no mechanical handling appliances are necessary.

For guns larger than 5-inch, the powder and the projectiles are usually stored, handled, and loaded separately.

The 6-inch projectile weighs about a hundred pounds and can easily be carried short distances by hand. When, however, it has to be carried any great distance horizontally, or has to be raised to any considerable height, a mechanical appliance is desirable, though not essential.

The 8-inch projectile weighs approximately 300 pounds; the 10-inch, 600 pounds; the 12-inch, 1,000 pounds; the 14-inch, 1,600 pounds; and the 16-inch, about 2,400 pounds. To handle projectiles of these weights mechanical appliances are essential.

The powder for the 6-inch gun is usually put up in a single cartridge, neither too large nor too heavy to be easily transported by hand. The 8-inch powder charge, likewise, is not too heavy to be carried by hand. If the charge for a gun larger than 8-inch be put up in a single cartridge the charge becomes too heavy for manual transportation and, moreover, becomes quite large and unwieldy.

Up to about two or three years ago the powder charges for even the largest guns were furnished by the Ordnance Department in several cartridges, weighing as a rule not over 80 pounds each, the 10-inch charge consisting of two cartridges, the 12-inch and the 14-inch, of four, and the 16-inch charge of six cartridges. These comparatively small cartridges could, therefore, be easily handled by hand.

However, experience has shown that when the charge for a large gun consists of several cartridges there is apt to be an irregularity in the rate of ignition of the charge when the gun is fired. This results in irregularity in powder pressure which affects initial velocity of the projectile and therefore the range. To avoid this, it is understood to have been tentatively decided by the Ordnance Department that hereafter the charges for all guns, at least as large as the 14-inch, shall be put up in a single cartridge. Whether or not this is to be done also for the 16-inch is understood to be still under discussion. Certainly the storage and handling of the 16-inch charge, which weighs about 600 pounds and is nearly 9 feet long, would be much simplified if it can be divided into at least two cartridges.

AMMUNITION SUPPLY.

In its full meaning, the term ammunition supply includes manufacturing the ammunition, transporting it to the seacoast fort, moving in to the vicinity of the particular battery, carrying it into the magazine, and storing it away in the magazine. The manufacture of the ammunition pertains to the Ordnance Department; transporting it to the fort, to the Quartermaster or Transportation Corps; moving it, after it reaches the fort, to a place in the vicinity of the battery is usually a function of the Quartermaster or Transportation Corps, though, as will be noted, the Engineer Department may be interested in a way; carrying the ammunition to the magazine and storing it therein is a question in which the Engineer Department is interested to the extent that it must supply all appliances necessary for this movement of ammunition.

The movement of ammunition from the point where it reaches the post to the vicinity of the battery is one which in time of peace has to be but seldom performed, for after the magazines are once filled the only movement of ammunition necessary will be to replace that expended in target practice and this is usually quite small. For these reasons, it has seldom been considered necessary to provide special transportation facilities for ammunition supply.

Prior to starting work on a battery, it is customary for the Engineer Department to build a railroad to the battery for bringing in the materials used in construction. After the battery is constructed, it was formerly customary for the Engineer Department to remove this railroad. In some cases, however, the railroad was left and was turned over to the Quartermaster Corps for maintenance and for such operation as might be necessary in carrying supplies to the battery. In a few places, as at Fort Monroe, this railroad, originally constructed by the Engineer Department, has become an important transportation feature of the post and is utilized for carrying troops back and forth to drill. In others, however, the railroad is used but seldom and is not always maintained in the best of condition.

It is the opinion of many Engineer officers, however, that the provision of proper facilities for bringing ammunition and other supplies to the battery should be considered when the battery is under construction. This was done by the writer in connection with all the Panama fortifications designed by him. In every case it was planned that the railroad tracks provided for construction purposes should, as the battery approached completion, be extended to some part of the emplacement, whence the movement of ammunition to the magazine could be conveniently made. (See Plates XXIII, XXIV, and XXV.) The plans of all the batteries show these supply tracks, and they show, in addition, trolley rails extending over the tracks, so that the projectiles, if desired, can be picked up by a trolley directly from the railroad cars in which they are brought to the battery and can be moved by trolleys to the shell room: the same means also can be used, if desired, for handling powder.

In one battery built on the top of a high hill, an elevator was provided. The shaft extended from a tunnel dug into the foot of the hill, up to the magazine floor, several hundred feet higher. For ammunition supply in another battery a cableway was provided for taking ammunition from the railroad cars at near sea level up to the end of a corridor passing in rear of the various emplacements.

In most of the older batteries built several years ago in this country no such provisions were made: although in connection with the use of ammunition cranes, which were needed, at least as an alternative method, for raising the projectiles to the loading platform, trolley tracks quite frequently led all the way to the rear doors of the emplacements. (See Plates XV to XX.) Consequently, in ammunition supply, if the projectile could be carried or rolled to within reach of the trolley, the movement for the remainder of the way to the shell room was simple. In fact, even after the use of the cranes was abandoned, and the cranes themselves were removed, the trolley rails were retained on account of their usefulness in ammunition supply, and quite frequently were extended out by brackets so as to project as much as 5 feet or so behind the rear face of the emplacements.

The means to be provided for bringing ammunition to within reach of the trolley rails and trolleys are rather difficult to standardize because they are to such a great extent dependent upon local conditions. They must, therefore, be left to the local officers.

AMMUNITION STORAGE.

Ammunition for small caliber guns, that is, 5-inch and under, which, as has been stated, is usually issued as fixed ammunition put up in metallic cartridges, is usually supplied by the Ordnance Department, and is transported to the battery in wooden boxes or cases containing several rounds. It is usually kept in the form in which it is received until just before it is to be used, when the boxes are broken open. Its storage, therefore, consists simply in piling up the boxes in the most convenient arrangement.

For 6-inch and larger guns the powder and the projectiles are stored and served to the gun separately.

Projectile Storage.

It was formerly customary to store projectiles in rows along the walls of the shell room with their points toward the wall so that the bases could be gotten at for inspection or placing fuzes. The lowest tier of projectiles was usually laid on a pair of timber skids 3 or 4 inches in thickness, and similar skids were placed between the successive tiers. For convenience in placing the projectiles in their rows, and in subsequently serving them to the guns, trolley rails were fastened to the ceilings of all 8-inch and larger batteries, passing over the centers of gravity of the projectiles in each row. No trolleys are provided in the shell room of 6-inch batteries because the projectiles are not heavy enough to require them. The number of 6-inch projectiles for which storage space is to be provided in the shell room is expected to be too great to permit storage in two rows only. It is intended, therefore, that in addition to the rows along the walls, other rows will be placed down the center of the shell rooms, so arranged, of course, that the bases of all projectiles will be along a passageway. These additional rows are usually shown on the mimeograph drawings of the 6-inch batteries. (See Mimeograph No. 59.)

The method of storing larger projectiles so close to the walls proved to be somewhat inconvenient, and in preparing the drawings for the 14-inch emplacements, published in 1908 (mimeograph 109, Plate XXII), the shell rooms were arranged for two rows of projectiles, leaving not only a passageway between the rows but also between the points of the projectiles and the walls.

These designs embodied also another new idea, that of storing the lower tier of projectiles not on the floor but on special storage tables, approximately of the same height as the receiving tables of the hoists. This was intended to facilitate ammunition service, and will be again referred to under that heading.

In the Panama batteries, the idea of keeping the projectiles away from the walls was adhered to, but instead of having two rows down the center of the shell rooms, two shell rooms are provided for each gun, the projectiles being stored down the center of the room with one passageway on each side of the row. (See Plates XXIII to XXVI.) The other new idea of the 1908 type of 14-inch emplacement was likewise adopted, but in part only. Instead of having shell tables extending the whole length of the shell rooms, they were provided at the service ends only, each table being large enough to hold eight projectiles ready for instant service. The tables are at just the proper height to permit the projectiles to be rolled directly into the shell trucks. By using short shell tables only, the floor of the rest of the shell room is left for projectile storage and a much larger number can be stored. This being a matter of ammunition service, it will be again referred to under that heading.

In the Panama mortar batteries still another idea of projectile storage is tried, that of raising the floors of the shell rooms, except near the doors, to nearly the height of the service table; this likewise was intended to facilitate the service of the projectiles.

Wherever two types of projectiles are furnished, it is expected that they will be segregated in the shell rooms, either by piling them in different rows or at least in different parts of the same row.

Powder Storage.

Powder is usually put up in hermetically sealed metallic cases and, for transportation, these are inclosed in wooden boxes or cases and are carried into the magazines in this shape. Sometimes the metallic cases are left in these wooden boxes and sometimes the wooden boxes are broken open. The cases containing the individual cartridges are cylindrical and, as long as the charges for all larger guns were put up in several cartridges, the lengths of these cylinders, as a rule, did not much exceed their diameter. It was customary to store them in the magazines with their axes vertical, piling, if necessary, some cases on top of others.

It was feared that during a rapid engagement when much powder had to be handled there might be considerable confusion between the empty cases and those which had not yet been emptied. To avoid this it was proposed to store the powder cartridges in metal racks in which they might be classified. The designs of the 14-inch emplacements shown in Mimeograph 109 and the plans of the powder magazines for the Panama fortifications were all based on the supposition that the metallic cases holding the cartridges would be stored in the magazines in such racks. The cartridge cases were to be laid on their sides in the rack, with their ends projecting into the passageway. When a cartridge was desired, the solder strip was to be pulled off without moving the cartridge case from the rack. This loosens the top of the case and the cartridge is then pulled out, leaving the case still fastened in its proper place.

The idea of storing the powder cases in racks as described, was abandoned because, before the racks could be provided, it had been decided by the Ordnance Department to furnish the powder for these large guns in single cartridges. These single cartridges are very large and in some cases are heavy enough to be quite unwieldy. Magazines for the storage of the long cartridges should preferably be of quite different shape from those most suitable for the storage of the small ones and, consequently, the magazines actually provided for the recent batteries are not as conveniently shaped and arranged as they would have been had the change been foreseen.

The question of the best method of storing and handling these long and unwieldy cartridges is now being studied and, as far as is known to the writer, a definite and thoroughly satisfactory solution has not as yet been developed. In some batteries it was proposed to store the cartridges in the same manner as projectiles, that is, lying on their sides, crossways in the room, and with passageways between the ends of the cases and the side walls of the magazines. Of course, they would be stored several tiers high. For convenient handling, a pair of twin trolley tracks was to be installed on the ceiling with twin trolleys to pick up both ends of the case at the same time. A powder service table, likewise, was to be provided. However, all such installations of powder trolleys and powder service tables have had to be suspended pending a final determination of the question as to the exact form in which the powder is to be furnished by the Ordnance Department.

One difficulty that has been met with in handling the long single-cartridge powder charges for very large guns is in getting the cartridges out of the metallic cases. To open the case at one end and attempt to lift or pull the cartridge out may result in tearing it unless special canvas ribbons have been provided that pass around the base of the cartridge, and even with them it appears almost necessary to tip the case up till its base is considerably higher than its open end. It has been suggested that both ends of this case might be opened and that the cartridge might be pushed out from the base. Another suggestion has been that to avoid having to handle the very flexible long cartridge it might be carried in the metallic case itself all the way to the breech of the gun and be pushed right through the case directly into the breech of the gun.

The question of powder storage has also been somewhat complicated by the practice, now customary with the Coast Artillery, of what is called "blending" the powder just before target practice. They open up a number of the metallic powder cases and then open and repack the cartridges, putting in each new cartridge an equal amount from each of the old ones. This is supposed to insure a more uniform action of the powder.

Sometimes the blending is done in the magazine, sometimes in a special small room, and sometimes outside of the battery. In some batteries a special small rehandling room has been provided for the purpose. Such a rehandling room is specially necessary at mortar batteries, where charges of several different weights have to be put up for fire in the different zones. This will be discussed more at length in the chapter on mortar batteries.

AMMUNITION SERVICE.

As has been stated, ammunition service is the movement of the ammunition from the magazines to the gun, and is a process which must be performed with the maximum possible speed. In considering the speed of ammunition service, it is not so much a question of the total time necessary for any particular projectile or powder charge to get from the magazine to the gun, but rather of the time interval between successive projectiles or powder charges. The magazines must be in a safe place and may be quite distant from the gun, so that there may be several different stages in the service of the ammunition. The critical time, therefore, is not the total time needed for serving any piece of ammunition, but the interval between successive charges in the slowest stage of the ammunition movement. In time of war a battery is supposed to be always in commission, and at least partially manned. On the approach of the enemy, more or less timely notice may be expected from the intelligence service, and when he is known to be in the vicinity, as many stages of the ammunition service as may be necessary can be performed in advance; even to partially loading the gun, so that the gun can be fired promptly when the enemy comes within range and fire can be continued rapidly thereafter.

In the discussion in this chapter, ammunition service will be considered in its general principles only, the detailed application to each particular type of emplacement being considered in the next chapter on the general subject of emplacement design. In that chapter the gradual development of the different types of emplacement will be discussed; for each type, the character of ammunition service designed for it will be stated and it will thus be shown historically how ammunition service has been gradually improved.

In the service of ammunition and, for that matter, in ammunition supply also, the ammunition may have to be moved either horizontally or vertically, or in a combination of these two directions. Since the appliances for horizontal and vertical movement differ somewhat, they will be discussed separately.

Horizontal Movement.

Ammunition can be, and in fact is, moved horizontally in several different ways: By hand; by handbarrows; by cars or trucks; by being rolled on a horizontal surface such as the floor, a table, or steel rails; or by being suspended from a trolley moving on a trolley rail usually fastened to or hung from the ceiling.

Moving ammunition by hand is the method used in practically all cases when the weight of the individual parts to be carried is small enough to permit it. It is used to the exclusion of other methods in the service of 5-inch guns and all smaller guns, and in the powder service of the 6-inch gun. Occasionally, in addition, it is used for carrying the 6-inch projectiles and the individual cartridges that make up the powder charges of the larger guns.

In moving ammunition by hand, the movement may be all on the same level or it may be up or down stairways or ramps. In some cases, one man will carry the ammunition all the way from the magazine to the gun, and in others it is passed from hand to hand; or it may be picked up by one man from one place and be pushed or carried by him to another place, where it will be picked up by another man. None of these cases, however, require further discussion.

The method of moving ammunition by means of handbarrows, carried by two or four men, is now the standard method of powder service for large guns. The barrows are either furnished by the Ordnance Department or are improvised by the detachment. They are sufficiently large to carry all the cartridges that go to make up a complete powder charge, or to carry the single large cartridge if the powder be put up in that form.

The trucks for carrying projectiles and powder along the horizontal or nearly horizontal floors of rooms, corridors, galleries, and platforms are usually furnished by the Ordnance Department, although in a few cases of very special emplacements the trucks have been specially designed and furnished by the Engineer Department.

The trucks usually furnished by the Ordnance Department for carrying 6-inch projectiles are designed to carry several at a time, crossways on the truck. These trucks carry the projectiles from the magazine to or as near the guns as they can go, and at this place members of the detachment pick up the projectiles and carry them by hand to and insert them in the breech of the gun.

The trucks furnished by the Ordnance Department for use with the larger guns have usually been designed for carrying the projectiles only, one at a time, the powder being carried by hand or by handbarrows. For several years, however, a type of truck was standard for use with large guns which carried the projectiles in a main tray high up and the four cartridges of the powder charge in two side trays lower down. (In figure 1, Plate I, there is a drawing of the rear elevation of such a truck.) The trucks for carrying projectiles only are quite similar except that the powder trays are omitted.

The trucks for larger projectiles carry the projectiles lengthwise and at such a height that they can be pushed directly into the breech. It was intended by the Ordnance Department that the projectile trucks should be rolled slowly up to the breech of the gun and that the ramming should be done while the projectile was at rest. Starting a heavy projectile along the loading tray by pushing is, however, somewhat difficult and to avoid this there has grown up in the Artillery the habit of rushing the shot truck against the breech of the gun on the run. The moment the truck strikes the breech it stops, but the projectile by its inertia is thrown forward into the breech of the gun, and, after a little practice, the detachment becomes so skillful that the men at the rammer are able to place the head of it against the breech of the projectile before the latter stops, and the ramming of the projectile into the breech of the gun is thus effected almost without labor. It is needless to say that this method of operation tends to batter up and wear out the projectile trucks and is, therefore, opposed by the Ordnance Department. It does, however, have the great advantage of ease and rapidity of service and will probably be continued in practice.

In order to make the ramming of the projectile into the gun as easy as possible, the breech of the gun in the loading position should be at that height which makes the ramming most convenient. It has been found by experience that the best elevation for manipulating the rammer is when the center of the breech of the gun is about 46 inches above the level of the platform on which the detachment stands. Consequently, the elevation of the loading platform when built is usually so arranged with regard to the other portions of the gun carriage as to make about this difference of level.

In order to provide for the possible breakdown of trucks, it is usual for the Ordnance Department to furnish several for each gun. This, in addition to providing spare trucks for emergency use, makes it possible to keep several of them loaded and in close proximity to the guns. These trucks when not in use have to be stored away and recesses for this purpose are shown in many of the mimeographs. (See Plates XVI, XVII, and XX.) Usually the truck recesses are located in the parapet wall along the front face of the loading platform. In the older emplacements it was not unusual to floor over the wells, which formerly held the balanced platform hoists and to use the recesses thus made for storing the spare trucks. (See Plates XIV and XVIII.)

A projectile is more or less cylindrical in shape and moving it horizontally by rolling on a smooth surface would naturally suggest itself to anyone. In fact, as will be noted hereafter, rolling the projectiles for a short distance along a floor formed one of the regular stages of the ammunition service of the earliest disappearing emplacements.

The old-style projectiles with blunt points could be rolled quite easily and when rolled would travel straight with no tendency to change direction. The modern long-point projectile, however, has its center of gravity so far back as to make it somewhat difficult to roll, since any slight obstacle has a tendency to cause it to swing or spin around.

Rolling projectiles, however, has an important disadvantage. All projectiles now used are fitted with copper bands to take the rifling of the bore of the gun and thus give the projectile, in its flight, a rotation about its axis. This copper band projects from the circumference of the shell and if the shell be rolled along a floor or table having a hard surface the copper band is quite apt to be injured. Consequently, whenever projectiles have regularly to be rolled horizontally, arrangements are usually made so that this motion takes place on rails, imbedded in a table and so spaced that the copper bands will come between the rails and will, therefore, not be damaged as the projectile is rolled. Such an arrangement of rails is made on the receiving and delivery tables of all hoists, and on the service and storage tables in all shell rooms. (Figures 3 and 4, Plate I.)

Powder cartridges when in the metal cases in which they are shipped and stored can of course be moved by rolling, but this is apt to injure the cases and should be resorted to but seldom. The wooden dummy cartridges of the same size and weight as real powder cartridges, which are sometimes furnished for and used at drills, can, however, be rolled readily and with impunity. This, though, is not true of the real cartridges which are usually more or less bumpy and soon lose their shape. Consequently, in designing the special hoists intended for raising powder cartridges, it was necessary to build the receiving and delivery tables on quite a slope.

For moving ammunition horizontally, the method of suspending it from trolleys has many advantages. With properly designed rails and trolleys, friction is very small and the rails, attached as they usually are to the ceilings, are quite out of the way. Of course, these trolley rails should, as a rule, be practically horizontal throughout their whole length; though, where there is a gentle slope to the ceiling and it is in the direction of the main movement, there is no reason why the trolley rails should not also be given a slight slope, provided the slope is not so great as to cause the trolleys to start to roll of themselves. When the trolley rails pass through rooms, galleries, or corridors where the ceiling elevations differ, it is usual to attach them to the lowest ceiling and, in other rooms, to suspend them at the same level by suspension rods attached to the higher ceilings.

In the earliest form of trolley rail, an ordinary **I** beam was attached to a flat ceiling by bolts through its upper flange, or suspended by hangers where the ceiling was high. This **I** beam form of trolley rail had the great advantage that considerable spans could be made with it and when the sections of the **I** beams used as trolley rails were of considerable length no difficulty was met with in keeping the rails in proper alignment.

The first form of trolley used with the **I** beam trolley rail consisted of a pair of wheels running on the lower flange on either side of the beam, and held together by a U-shaped yoke hanging down under the beam. Some difficulty was met with in connection with this form of trolley. Each wheel, of course, revolved about its own axle and the two axles had to be held in their proper relative positions by the yoke. Through some faulty construction or for some other reason these yokes had a tendency to bend outward and to allow one or both wheels to drop.

The next form of rail used and the one that has probably been used more than any other is the so-called "Coburn" trolley track, manufactured by the New Jersey Foundry & Machinery Co. (See figure 6, Plate I.) The Coburn rail is in the shape of an inverted letter ∩, with the lips turned inward and upward. The trolley wheels are inside of this rail and roll in the grooves made by the upturned lips, the suspension bars hanging down between the lips. Theoretically, one double trolley wheel might suffice, at least for small loads. But in fortifications no use is made of so simple a form. The simplest form applied to practical uses consists of a pair of double wheels, placed one behind the other and connected by a horizontal bar.

from the center of which is hung another suspension bar. Of course, any weight placed on this suspension bar is transmitted equally to the two double wheels. When a heavier load is to be carried, two suspension bars, each supported by a pair of double wheels, can be brought together and be themselves connected by a longer horizontal bar to the center of which the load can be applied. This method, which transmits the weight equally to four double trolley wheels all in tandem, is the one in most common use in fortifications.

The trolley rail itself is supported at intervals by hangers somewhat similar in general shape to the rail itself, but having in addition upper flanges by which it can be bolted to the ceiling. (See figure 6, Plate I.) All of the details of this trolley system are shown in the pamphlet issued by the manufacturer and usually sent to Engineer officers upon request.

This form of trolley rail has the disadvantages, first, of requiring more headroom than the **I** beam rail because all loads must be attached well below it; and second, of being manufactured in short lengths only, and therefore somewhat apt to get out of line. On the whole, however, this system has given satisfaction and for some 10 years or so was the standard for fortification use, at least in trolley systems consisting merely of a single line of rail or of simple loops only.

Frequently, however, it is desirable in any trolley system to have switches so that the trolley may be sent over either one of two alternative routes. With the old form of **I** beam track and with the Coburn tracks also, these switches are somewhat difficult to build so as to make them accident proof, as there is always the possibility of their being turned the wrong way when the trolley arrives.

This difficulty has been obviated in a new trolley system invented a few years ago by a Mr. James Y. Moore of the firm of Chisholm-Moore Co., of Cleveland, Ohio. This system made use of an ordinary **I** beam as the trolley rail and of a specially designed "frog" having no movable parts so that it can not get out of order. (See figure 7, Plate I.) A 7-inch **I** beam and frog are used for handling the 12 inch and 14 inch projectiles and an 8-inch **I** beam and frog for the 16-inch projectiles. The wheels of the trolley, which are very easy running, roll on the lower flanges of the beam, one on each side, and are held together by a well and strongly built yoke. On approaching the frog, the trolley chain is pulled to one side, the trolley automatically switches to the side toward which the chain is pulled, and takes one of the two branch tracks that make an angle of 24° with each other and of 12° with the line of the main-line track produced. When moving in the reverse direction, the trolley passes easily from either branch track back to the main line. For use with this trolley and frog, Mr. Moore has invented an easy-hoisting differential block and a new form of telescoping shell tongs which saves considerable headroom, which in magazines is an important item. He has developed, in addition, a new form of fastening, which permits the hold-up bolts to be inserted in the concrete ceiling when poured and yet gives considerable play when the I beam is to be put in place. All of these details are shown in the pamphlet published by the manufacturer. The trolley system has so many advantages that it was adopted as the standard in the Panama and most of the more recent batteries.

In designing an emplacement, the layout of the trolley tracks is a subject which should receive more thought than apparently has always been devoted to it.

In the old mimeograph drawings of gun emplacements, paths for the trolley tracks are shown. These paths pass over the storage piles of projectiles and, of course, over the receiving tables of the hoists, and they sometimes extend to the outer doors, for use with the cranes, and in ammunition supply. (See Plates XV to XX.) Unfortunately, however, they have usually been what may be called "single track" only. That is, when a particular trolley had been used to bring a projectile from the shell room to the receiving table of the hoist it had to be pushed back over the same path before it could be again used. Of course, several trolleys might be used at the same time and they might be manipulated in a gang, being pushed forward and back together, but this inevitably means some loss of time somewhere. To obviate this trouble there was introduced in the 12-inch battery constructed by the writer at Fort Monroe in 1904 and 1905, the policy of laying out the paths of all trolley tracks, or at least the portions of these paths necessary for ammunition service, in loops, so that when one trolley has been used to bring a projectile from the shell room to the receiving table of the hoist, it may be pushed on around the loop and thus not interfere with the use of subsequent trolleys on the same loop. By doing this and by having a sufficient number of trolleys, the shells can be handled at any desired rate.

The system of laying out all ammunition service trolley tracks in loops is now the standard policy and has not only been introduced in all recent emplacement designs, as will be seen by examining the plans of the Panama batteries both direct fire and mortar, but in many cases has been applied to the older batteries, the trolley systems of which have been altered. (See Plates XXI to XXVI and XXIX.)

In addition to the trolley rails necessary in ammunition service, additional trolley rails should be extended to the exterior of the battery for use in ammunition supply. These ammunition supply trolley tracks should extend not only to the doors but should also, if possible, be carried farther so as to pass over the cars or vehicles in which the projectiles are to be brought to the battery. (See Plates XVIII to XXV.)

Moving Ammunition Vertically.

In order to be able to raise heavy projectiles an appliance for seizing hold of them is necessary, and for this purpose projectile tongs are used. For each size of large projectiles the Ordnance Department furnishes projectile tongs which work on much the same principle as ice tongs, there being, however, three prongs instead of two, two on on one side of the projectile and the third on the other, located so as to close between the two. To take hold of a projectile, these tongs are opened wide and are then placed around it as nearly over the center of gravity as can be estimated. The tongs are then closed and clamped and the projectile is ready to be moved.

With these ordnance tongs, however, several inches of vertical height are lost between the projectile and the eye in which the hook of the chain is inserted. This loss of distance becomes important in some cases where head room is scarce.

To avoid this trouble and, incidentally, to improve the tongs in other details, the same Mr. Moore who invented the trolley-rail frog mentioned above, invented also a new type of projectile tongs in which the third prong telescopes between the other two when the tongs are opened. These tongs can be used with any form of trolley, but when used with the Chisholm-Moore trolley, for which they were specially designed, they save fully 15 inches of head room, as compared with the form of Yale & Towne block and the Ordnance shell tongs which were formerly the standards.

For raising projectiles short distances, especially in connection with the use of a trolley, and occasionally even for raising projectiles through a considerable vertical height, the appliance most commonly used is a differential block, the friction of which is sufficient to prevent the projectiles descending of its own weight but yet is so small as to permit it to be raised or lowered by overhauling the operating chain without any undue expenditure of energy.

The old form of Yale & Towne differential or "Triplex" block has for many years been the standard appliance used for this purpose, and still is quite serviceable. For places, however, where there is but scant head room, or in new emplacements where the provision of much head room increases the cost of the work the newly-invented Chisholm-Moore differential block has many advantages and has been adopted as the standard in the Panama and other recently constructed fortifications.

Of course, in raising projectiles by means of these differential blocks considerable energy must be expended, and the question has been several times considered as to whether or not it would be desirable to install special electric appliances for doing this work. After careful consideration, however, it has been decided that since the distance which the projectiles have to be raised by these blocks is usually not great, the amount of work saved would not be sufficient to compensate for the complications necessarily involved in the installation of electric power. In very exceptional cases where the projectiles have to be raised great distances it might pay to use electrically operated blocks.

In the interior of the earliest emplacements, where ceilings were available for attaching trolley rails, the differential block just mentioned was the appliance used for raising the projectiles from the floor. Outside of the magazines the platforms were uncovered and trolley rails could not be used, so cranes were substituted.

These cranes (see figures 1 and 2, Plate II) consisted essentially of a vertical rod or bar, bent at its upper end so as to extend out horizontally some 3 or 4 feet. At the outer end of this bent portion there was attached for suspension purposes a ring or hook. The foot of the crane was inserted in a socket or bearing plate, usually some 2 feet or so from the foot of the vertical wall, and the crane was held in a vertical position by passing through a collar in a bracket attached to the upper part of this wall. By rotating the crane about its vertical axis, the suspension ring would describe a circle in a horizontal plane, and this gave articles suspended from it a small horizontal movement.

The actual hoisting was done by different methods; in some cases a differential block was used, similar to those in the magazines though having a little greater vertical range. In other cases, a regular block and fall was installed, the hoisting line being led to a winch attached to the vertical part of the crane. Sometimes the block and fall would be omitted and a single line would be used for hoisting, passing through a pulley suspended from the ring and thence to the winch. Several of the early mimeographs were devoted to the details of these cranes, but being obsolete, no further reference to them is necessary. When the crane was used for ammunition service in the older emplacements the projectile to be raised was rolled to within reach of the crane, which picked it up and raised it to above the level of the loading platform. The crane was then swung around and the projectile lowered into a projectile truck on the loading platform.

In the emplacements designed about 1894 to 1896 the crane was an essential portion of the ammunition service provided. Later emplacements were, as a rule, provided with platform hoists or standard chain hoists and the cranes became no longer necessary. However, it continued for several years to be the custom to install cranes as an alternative method of raising projectiles should the regular projectile hoists be for any reason out of commission. They are shown on all emplacement designs issued by the Engineer Department up to and including the designs for the 14-inch emplacement, published in 1908 as mimeograph 109. However, in a few years the projectile hoists showed themselves to be so reliable that the cranes were not used. Later it became the custom not to install cranes in new emplacements, and eventually they were removed from the old emplacements in which they had been installed and were scrapped.

Cranes somewhat similar in general design to those used in emplacements were, until very recently, installed by the Ordnance Department for ammunition service in connection with large barbette carriages. The cranes for this purpose were mounted upon the long metal loading platforms attached to and forming part of the rear of the barbette carriages and revolving with the carriages as they moved in azimuth. The actual hoisting was sometimes done by a differential block and sometimes by a windlass. Occasionally, however, where the distance the projectile had to be raised was large, a simpler and somewhat more rapid method of hoisting projectiles was used with these cranes. A block and fall was attached to the suspension ring. The hoisting line, instead of going to the winch on the crane, passed down and through a snatch block at the base of the crane and thence out horizontally. On the level platform around the base of the gun carriage was stationed a gang of from 8 to 12 men who, by seizing hold of the hoisting line and walking away with it, could rapidly raise the projectile.

When, by means of a crane, the projectile is raised to the level of the breech of the gun, the crane is swung around so that the point of the projectile is inserted in the breech. The hoisting line is then gradually slacked away as the projectile is rammed into the gun. It requires considerable care to do this well and quickly.

The handling of projectiles by means of cranes was somewhat slow, and about 1896 there was substituted for the cranes an apparatus known as the "balanced platform hoist." (See figures 5, 6, and 7, Plate II.) This apparatus consisted of two platforms about 3 by 4 feet, operating in two wells a few feet apart. The platforms were connected by means of a wire rope so that one would counterbalance the other and, consequently, as one went up the other would go down. A wire rope was attached to one of these platforms and passed thence up over pulleys at the top of the well, to and around the operating wheels of a winch, up over pulleys at the top of the other well, and thence down to the other platform. The length of the wire cable was supposed to be such that when one of the platforms was exactly on the level of the magazine floor, the other would be exactly on the level of the loading platform. By operating the winch, the upper platform would be lowered to the magazine floor and the lower platform would be raised to the loading platform level.

These platforms were made of such a size as to just contain the standard ammunition truck used at that time. (See figure 1, Plate I.) This truck had an upper and central tray for carrying the projectiles and two lower side trays, one on each side, for carrying the powder cartridges. A truck would first be rolled to or near the shell room and a projectile placed on the central tray, thence it would travel past the powder room and the powder would be placed on it. The truck was then rolled on to the lower platform of the platform hoist and, at about the same time, an empty truck would be placed on the upper platform. The winch was operated, raising the loaded truck and bringing down the unloaded one. When the loaded truck reached the loading platform level, it would be rolled out for service to the gun and at the same time the empty truck would be rolled out on the magazine floor for loading. Since the platforms exactly balanced each other, as did the trucks, the net weight to be moved in any case was merely that of the ammunition.

These winches were intended to be operated normally by an electric motor, but arrangements were made so that, in the absence of electric power, the winch could be operated by hand.

When new, the platform hoists worked quite well, but unfortunately, as they began to wear and the wire ropes stretched, it seemed to be almost impossible to keep the lengths of the ropes properly adjusted, and if this were not done, the platforms would not come to the level of the floors at the same time which made it somewhat difficult to roll the trucks on or off the platforms.

In the meantime, however, several officers had been experimenting with continuous chain hoists. Such a hoist (see figures 1 and 5, Plate I) consists essentially of two exactly similar sprocket chains, formed into loops of the same length. The upper bends of these two chains pass over and are supported by two exactly similar sprocket wheels fastened to the same axle which is supported by a frame work on the upper level of the emplacement. The loops of the chains, of course, hang down and in the lower bends of these loops are hung two exactly similar sprocket wheels, likewise attached to an axle. This axle fits into bearings in two side frames and has on it, in addition to the sprocket wheels, a gear wheel, geared up with the other wheels of a winch. By working the mechanism of the winch, the lower sprocket wheels are turned, thus causing one part of each chain to go up and the other to go down. At intervals along these chains, and at the corresponding links of the two chains, are attached carriers which, of course, go up and come down with the chains. As the carriers are moved up they pass through slots in a specially designed table called the receiving table and pick up from this table the ammunition which is to be raised. This ammunition they carry up and eventually deliver to an especially designed table called the delivery table, which is located on the upper level of the emplacement.

The detailed drawings and descriptions of the different chain hoists which from time to time have been developed, as well as instructions for their care and operation, have been published by the Engineer Department in Mimeograph 46, its different supplements, and the drawings accompanying them. To correctly understand all the details of the hoists an examination of these mimeograph drawings will be necessary, but outline drawings showing the general principles are given in Plate I.

There are two essentially different classes of these hoists known as the front delivery and the rear delivery type. In the front delivery hoist, the table upon which the ammunition is delivered by the carriers is practically directly over the receiving table from which the ammunition is taken up. In the rear delivery hoist (figure 5, Plate I), the ammunition is carried over the axle of the top sprocket wheel and is delivered on the opposite side of this axle, and therefore of the hoist.

The choice of the words "front," and "rear" or "back," to distinguish these two classes of hoists, is unfortunate, because, in almost all other phases of fortification work the words "front" and "rear" have special techinical meanings. The word "front" always means the direction toward the enemy and the word "rear" the direction away from the enemy.

Fortunately, however, in this particular case, the use of the words "front" and "back" has not, and probably will not, cause much confusion, because the front delivery hoists soon became obsolete. They were intended for use in a type of emplacement designed before the invention of the hoist. (See Plate XV.) Shortly after its invention, this type of emplacement was discarded and no others were built. All subsequent emplacements were designed for the rear delivery hoist and all the designs have been such that the delivery tables of these hoists actually point toward the rear of the emplacement.

There are three general types of hoists that have been used. In the first, the load is carried by bracket carriers held out nearly horizontal from the chains by means of wheels rolling in guides. (Figure 1, Plate I.) In the second, which is very similar to the first, the carriers are pushed up by the chains from below and have to be moved in grooves or guides to keep them from turning over. In the third type, the carriers are hung from chains, and being, therefore, in a position of stable equilibrium, grooves or guides are not necessary. (Figure 5, Plate I.) The first two types, which are very similar, are known as the Hodges types, they having been developed by Capt. (now Maj. Gen.) Harry F. Hodges, Corps of Engineers. The third type is known as the Taylor-Raymond hoist, from the two engineer officers who were specially concerned in its development, Capt. (now Brig. Gen.) Harry Taylor and Capt. (now Lieut. Col.) R. R. Raymond.

The first type was used in the 6-inch and 8-inch emplacements; the second, in the 6-inch, 8-inch, and 10-inch emplacements; the third, in all sizes of emplacements up to and including the 14-inch.

All of these types are readily adapted to rear delivery. The second type was also easily adaptable to front delivery, the carriers, as they approached the delivery table, being forced by their grooves to move out toward the table and to roll or push the projectiles thereon. As the chain continued upward the carrier then fell down in an inverted position and in that position passed over the upper sprocket wheel and down the descending part of the chian. As it passed around the loop at the bottom of the chain, the carrier was pushed back into its proper position.

The adaptation of the third, or Taylor-Raymond, type of hoist to front delivery was somewhat awkward, as will be noted from figure 2, Plate I. In this type of front-delivery hoist, the receiving table is placed on the side of the winch on which the chains descend and is made very low. As the carriers in their descent approach the receiving table, they are thrown out horizontally by guides and as the chain continues around the lower sprocket wheel the carriers by a sort of scoop motion draw the projectiles into themselves. In order that a projectile may be scooped up from the receiving table it must be in exactly the right place at the right time, and to insure this there is an escapement, operated by stops on the chain, which permits the projectile to roll into this position only at the proper moment.

The receiving tables of the hoists are ordinarily built so as to be about 3 feet or slightly more above the floor, as this has been found to be a very convenient height. (Figures 4 and 5, Plate I.) The delivery table (figures 1, 3, and 5, Plate I) is located on the loading platform level and its elevation has to be carefully adjusted to that of the projectile tray of the ammunition truck, the height of which is governed by the elevation of the breech of the gun above the loading platform level. As the projectile is delivered by the hoist upon the delivery table, it rolls to the rear until it comes against the buffers of an escapement. When an ammunition truck is in proper position just in rear of this escapement (figure 1, Plate I) the escapement is operated, allowing one projectile and one only to roll from the delivery table to the shell tray of the truck. When the elevation of the delivery table has been properly adjusted, the edge of the shell tray of the truck should be a very small fraction of an inch below the rear end of the rails of the delivery table.

All the types of continuous chain hoist have been fitted with electric motors for operation by electric power and this is supposed to be the normal method of using them. For emergency use, however, in case the electric power should fail, cranks have been provided for hand operation, although, of course, at much less speed. The normal chain speed for electric operation is at the rate of about 25 or 30 feet a minute and the carriers are usually spaced so that five or six carriers pass both the receiving table and the delivery table each minute. As originally designed, it was expected that one carrier would take the projectile and the two succeeding carriers, the powder cartridges to fire this projectile, so that two full charges could be delivered by a hoist in about a minute. Later, when it was found to be somewhat dangerous to raise both powder and projectiles by the same hoists, all of the carriers of the hoist became available for handling projectiles. It was then found possible to spread the carriers a little farther apart and to reduce the chain speed, still delivering projectiles at a rate of not less than three per minute. This, for large guns, is faster than they can be fired. The 6-inch projectiles can be sent up at a rate of from six to eight per minute.

Hand operation is, of course, much slower but it has been found that four men, two to each crank, can without undue fatigue raise 12-inch projectiles faster than, under ordinary circumstances, they can be fired, provided the men are relieved every few minutes.

The projectile hoist is ordinarily worked by electricity and it is the duty of the detachment at the receiving table on the lower story to feed the projectiles rapidly to the hoist. These men, of course, can not see and can not know the rapidity with which the projectiles are being removed from the delivery table above, and there is, therefore, danger of the projectiles being sent up faster than they are used. In this case the delivery table will soon become filled and, if filled, a projectile coming up on a succeeding carrier and not finding a place on the delivery table would be liable to be pushed off and fall down through the hoist well. Of course it is the duty of the detachment at the delivery table to prevent this by having the hoist stopped. This can be done by calling down through the hoist well, but as there might be so much noise and confusion that the call would not be heard, an arrangement is made so that they can, themselves, stop the hoist. There is installed alongside of the delivery table on the upper level a small electric switch, which, when opened, automatically stops the electric motor operating the hoist. The hoist can not be started again until the upper switch is closed. This will be again referred to in the chapter on electrical installation.

In all emplacements built up to about 1908, but one projectile hoist was installed, the cranes being relied upon as a reserve or emergency means of raising projectiles should the hoist become disabled. An additional precaution, however, the 1908 design for the 14-inch emplacements (mimeograph 109, Plate XXII) provides two hoists for each emplacement.

The second projectile hoist was provided not only as a spare in case the first one should get out of order, but for the following reasons: It was expected that the Ordnance Department would supply for each caliber of gun at least two kinds of shell, either shells of different weight or an ordinary shell and a high explosive shell. It might happen in the midst of an action that it would become desirable to change from one type of projectile to another. With but one hoist it would be difficult to make such a change, for until all of the projectiles of the old type then en route to the gun had been disposed of, either by firing them or laying them aside, the projectiles of the new type could not begin to arrive, since they would have to pass through all the stages of ammunition service up to the gun. With two hoists in operation, two different kinds of projectiles could be on the way to the gun at the same time, or the action might be started with the delivery table of one hoist filled with one kind of projectile and the delivery table of another hoist with another kind, so that the change from one type of projectile to another could be made practically instantaneously.

To provide an arrangement of this general character in an old battery where but a single hoist is in use, there was experimentally provided at Battery De Russy, Fort Monroe, in 1905, an additional "double delivery table." This double delivery table was placed immediately in rear of the regular delivery table of the hoist and had two sections, each holding four projectiles, and could be rolled from one side to the other so that either section of the special double delivery table would be in rear of the regular delivery table. One section would be kept in rear of the hoist and would be in constant use, the projectiles being rolled from the regular hoist delivery table right along to the special delivery table as fast as they could be received. The other section would be kept to one side in reserve.

It was assumed that an action would be started with both sections of the double delivery table filled or partially filled, one with one kind of projectile and the other with another kind. If the action was to be started with one kind of projectile, the section of the double delivery table containing that particular kind of projectile would be moved in rear of the hoist, and that kind of projectile would be the one sent up by the hoist and the one carried to the gun. If the order came to change, projectiles of the new type would be taken from the other section of the delivery table until that type of projectile began to come up on the hoist. Then the table would be shifted and the new type of projectiles as they came up would be passed right along the delivery table to the truck.

This double delivery table was used for some four or five years, but it was finally decided to be unnecessary and was discarded and scrapped. Since all modern batteries of the two-story type are provided with two hoists, it is not probable that the construction of another double delivery table will ever be necessary.

In one of the earlier designs for 6-inch barbette rapid-fire emplacement (mimeograph No. 40), it was considered desirable that a delivery table holding a greater number of projectiles should be provided and quite a complex form of such table was shown in the drawings. (See figures 3 and 4, Plate II.) First there was the ordinary delivery table immediately behind the hoist and provided with the usual escapement; immediately in the rear of the escapement, and running from side to side on a track was a transfer car, to which projectiles could be delivered by the proper working of the escapement. This transfer car would hold six projectiles, and when in its position immediately in the rear of the delivery table, these projectiles could be rolled right across it, to the middle section of a three-section reserve table. However, by filling the transfer car and then by moving it to the right or left on the rails set in the platform for the purpose, it could be placed immediately in the rear of the right or of the left section of the reserve table.

From the reserve table the projectiles were to be taken by hand to the gun or were to be carried on a special form of truck to a position more nearly in rear of the gun. Since each section of the reserve table would hold 12 projectiles, the transfer car 6, and the delivery table at least 3, not less than 45 projectiles could be conveniently stored on this complicated apparatus.

As far as is known, however, no battery of the particular type for which this table was designed was ever constructed, and it is probable, therefore, that no triple reserve table was ever used.

As has been stated, the projectile hoists are designed to be operated normally by electric power, and in case this power gives out, then by hand.

As an additional precaution, arrangements are usually made for storing a few projectiles in niches on the loading platform level. Provisions for doing this were frequently made by constructing officers, although not shown in the mimeograph designs. However, in mimeograph 109, published in 1908, and showing designs for 14-inch emplacements (Plate XXII), niches on both faces of the parapet are shown, each containing small emergency storage tables for projectiles. These storage tables are provided with the same form of escapement as the delivery tables of the hoists and the projectiles can be moved from them to the shell trucks exactly as from the delivery tables. By storing projectiles of different kinds on these different emergency tables, a rapid change of projectiles during an action can be made quickly and easily. Later, during a lull in the engagement, the tables can be filled again. To fill them the projectiles are carried on the regular truck to the emergency storage tables and are rolled on to the tables by reversing the regular action of the escapement.

When the ammunition hoists are used, the projectile, when once elevated in the shell room by the block on the trolley to about the level of the receiving table of the hoist, is moved the rest of the way to the breech of the gun with but little expenditure of human energy, none being needed at any stage to raise the projectile higher. However, in raising the projectile from the floor to the level of the receiving table, considerable human energy must be expended. This was especially true in the older batteries where the supply of ammunition normally kept on hand was so small that the piles of projectiles were ordinarily but one tier high and never more than two.

In order to reduce the amount of labor necessary in raising the projectiles up to the level of the receiving table, there were tried experimentally in Battery Parrott, Fort Monroe, hoists with what were called "depressed" receiving tables. The winches and lower portions of the hoists, instead of being set upon the magazine floor level, as is usual, were placed in pits slightly below the magazine floor and slight modifications were made in the design of the receiving tables so that they were at the level of the floor. The pits extended along the sides of the receiving table so that the men working there would not have to stoop so low.

In this battery, therefore, a projectile stored upon the floor of the shell room may be rolled all the way along the floor to the receiving table. If the projectiles be stored on skids, all that is necessary is to raise it with the trolley hoist just far enough to clear the skid, and to then push it horizontally and lower it a few inches to the receiving table. In other words, in ammunition service, with this style of hoist, no raising of the projectile has to be done by human energy.

Apparently this new design should have worked well, but it was finally decided by the officers concerned that the labor of stooping over and handling projectiles on or near the floor was more fatiguing than to raise them up to the usual receiving table level. This type of hoist was, therefore, never used again.

In the 1908 design for 14-inch emplacements (mimeograph 109, Plate XXII), the trouble encountered in raising the projectiles was avoided by building for them in the shell rooms long storage tables, the levels of which were exactly the same height as the receiving tables of the hoists. In this type of emplacement two projectile hoists were provided and, immediately to the front of each receiving table, a storage table. By means of removable sections of rails, the storage tables can be made practically continuous with the receiving tables, so that, if desired, projectiles of the first tier can be rolled all the way from the storage tables to the receiving tables. Should there be sufficient projectiles to require storage in two tiers, removable rails were to be provided which could be placed upon the top of the first tier, and a removable receiving table was also provided, so that the projectiles of the second tier could likewise be rolled all the way to the removable receiving table.

In this system of ammunition service, the trolley in the shell room is not essential in ammunition service, although it is very useful in ammunition supply or later for shifting projectiles from one place to another. It could also be used in ammunition service as an alternative to the rolling of the projectiles if found more convenient.

The operation of raising projectiles with the differential blocks is quite fatiguing if done rapidly, but is not especially so when done slowly. In order, therefore, to obviate the necessity of operating the differential blocks rapidly, it has become the custom to install at the service end of shell rooms what may be called "service" tables. These service tables are of the same height as the trays of the projectile trucks and are fitted at the service end with escapements, similar to those at the end of the delivery tables of the hoists, so that projectiles can be rolled right from the service tables into the trays of the trucks.

An arrangement of this kind was first shown in the 1906 type of mortar battery, supplement to mimeograph No. 27 (see figure 7, Plate XXVIII), and since that time they have become a standard fitting for mortar battery shell rooms.

Similar tables sufficiently large to hold eight projectiles each were designed to be installed in the shell rooms of all the Panama heavy direct-fire guns. In these batteries the loading platform is on the same level as the floor of the magazine, and, consequently, hoists are not needed for ammunition service. The projectiles are rolled directly from the tables at the service end of the shell rooms to the trucks and are carried by the trucks to the guns. In all cases, both in the mortar batteries and the Panama type of battery, it is expected that an action should find the service tables filled with projectiles. As these are fired away, they are to be replaced from the piles of projectiles in the rear, but as several trolleys and their blocks can be used simultaneously, the work of raising the projectiles should not be exhausting.

A still handier method of storing projectiles is shown in the designs of the Panama mortar batteries (Plate XXIX). In this case the ceilings of the shell rooms are made quite high and the floors, except near the doors, are raised between 2 and 3 feet above the floors of the entrance galleries, that is, to such a level that the second tier of projectiles stored on these floors is at exactly the same height as the projectiles resting on the service tables. In moving the projectiles from the shell rooms proper to these service tables, therefore, the third and fourth tier of projectiles would have to be lowered in placing them on the service tables, the second tier would have to be moved practically horizontally, and the first tier only would have to be raised by an amount equal to their own diameter plus the thickness of a projectile skid.

Powder Service.

When the balanced platform hoists were used, the trucks raised by these platforms carried both the powder and projectile. When these platforms were replaced by the endless chain hoists it was but natural that the hoists should also be expected to carry up the powder as well as the projectiles, and, consequently, the early hoist drawings show one carrier raising a projectile and the two following carriers the powder. This powder charge is shown as consisting of four cartridges, two of which were carried by a single carrier. (See fig. 1, Plate I.) The dummy drill cartridges worked very well with the hoists, but when actual powder cartridges were used, it was found that they did not roll down the gentle slope of the delivery table as readily as did the projectiles, and, therefore, had a tendency to choke up this table at its front end. It therefore became necessary to stop using these hoists for raising powder and to use them for projectiles only.

The next step was to build separate powder hoists. Three types of these were developed for use under different circumstances, and many were installed in different large batteries throughout the country.

Of these three types of powder hoist, the most successful was somewhat similar in its general characteristics to the Taylor-Raymond projectile hoist, except that the carriers consisted of loosely hanging canvas bags, which were hoisted on a slope of about 30° or 40° instead of vertically, as in the projectile hoists. To insure that the cartridges would roll out of the way as soon as they reached the delivery table, this table was built on a very decided slope.

However, after powder hoists had been installed in many batteries, it was decided that it was not advisable to use them. It had already been found that the carrying of powder from the delivery table of the hoist to the gun on the same truck as the projectile was not very convenient. This part of the powder service was performed by men carrying the cartridges on their shoulders, the trucks being used for projectiles only. Shortly afterwards there was introduced for carrying the powder a sort of handbarrow carried by two or four men and which could hold all of the cartridges at once. The next step was to do away entirely with the powder hoist and to have the powder carried on these handbarrows or by hand all the way from the powder magazine on the lower level up to the loading platform on the upper level.

This is the standard method now in use and is, of course, equally adaptable to the use of the single cartridge charge. Whether or not it will be continued with the new proposed long 16-inch cartridge remains to be seen, but it is the opinion of the author that before long some special form of 16-inch powder truck will have to be developed.

As showing the general character of the ammunition service provided in the modern battery, I quote from the letter submitting to the Chief of Engineers the plans for two of the 14-inch Panama batteries:

> In the ammunition service proper of these batteries, hoists are not to be used. Each gun has its own double-shell room on the same level as the loading platform, and each double-shell room has two shell tables, so that two classes of projectiles can be kept available for instant use. Each shell table is large enough to hold eight projectiles, while in the rear of each a total of about 63 projectiles may be easily piled in not more than three tiers, so that 142 projectiles for each gun can be conveniently stored; nd by placing the projectiles closer together this number can be increased to 172, and by using a fourth tier still more can be stored. As the projectiles are used from the shell table, others are to be placed on the shell table by trolleys from the piles in the rear.
>
> The powder magazine of each battery has a capacity of 140 charges (four cartridges in each) stored in racks, five cartridges high. By making use of four tiers only, a total of 112 charges can be stored. It is expected that those stored in the fifth tier will be moved to the lower tiers in the racks during lulls in the engagement.
>
> As the use of the fifth tier of cartridges may prove inconvenient, it has been considered necessary to provide additional powder storage, which has been provided in one long room on the left side of the right traverse of Battery Burnside, this now being intended as a reserve powder magazine for all four of the 14-inch guns, the powder being removed from this reserve magazine to the regular powder magazines during intervals in an engagement.

OTHER MOVEMENTS OF AMMUNITION.

In addition to the moving of ammunition necessary in ammunition supply, such as carrying the ammunition into the magazine, and, in ammunition service, taking it from the magazine to the gun, it is sometimes desirable to move it at other times.

Where this is merely a question of rearranging the projectiles or powder in the shell room or powder magazine, no special arrangements are necessary; the same appliances which were used for getting the ammunition into the magazine, such as the trolley rails and trolleys, being available likewise for shifting it around.

There occurs, however, in certain batteries, an intermediate stage in ammunition storage when the movement of the ammunition becomes necessary.

In the early emplacements, when the amount of ammunition which it was considered should be kept on hand was not large, it was expected that all of this ammunition would be kept in storage under conditions which would make its service to the gun rapid and easy. More recently, however, the allowance for ammunition has been much increased. All storage space is expensive, and it has, in some cases, been considered unnecessary to go to the extra expense of making the magazines and shell rooms of these batteries so large that all of this enlarged supply of ammunition may be kept in what may be called "service storage."

This condition arose specially in two of the batteries in the Panama fortifications. (See Plate XXV.) Here only half of the ammunition supply is kept in service storage. For each of the guns in each of these batteries there are upper magazines and upper shell rooms on the same level with the loading platforms and in which are kept the ammunition that is ready for instant service. Immediately below these and on a lower floor are magazines and shell rooms of practically the same size as those above but in which the ammunition is supposed to be kept only in what may be called "supply storage."

During an engagement, ammunition will be taken, of course, from the upper or service magazines, and the supply kept there is much greater than can ever be used in a single engagement. In the intervals between an engagement, it is intended that the ammunition taken from the upper or service magazines and used in the engagement will be replaced by bringing up ammunition from the lower or supply magazines.

This movement of the ammunition from the supply to the service magazine, which is to be done between engagements, or possibly during an engagement, by the surplus men of the detachment, is one in which no haste is necessary and consequently the hoists need not be very rapidly moving. Those actually installed are comparatively simple, are operated by electrical means, and raise the ammunition through openings extending from the floors of the upper magazines to the ceilings of the lower ones. Since the conditions in these batteries are quite unique, this apparatus can hardly be considered standard and no special description is necessary here, but the drawings of this apparatus can doubtless be obtained by officers who may have need for them.

Another movement of ammunition which quite frequently becomes necessary is sending back to the powder and shell rooms, ammunition which has not been used. In action, of course, all the ammunition taken to the gun presumably will be fired, though there may at the end of an engagement be a small amount to be returned. In drill, however, the ammunition is not fired and, therefore, has to be restored to the magazine.

Consequently, all the modern projectile hoists have been so designed that not only can the projectiles be raised from the magazine to the loading platform, but so that they can likewise be taken back from the loading platform to the magazine level. In the Hodges hoist this was an operation requiring considerable care, but in the Taylor-Raymond rear-delivery hoist it can be done quite readily, the projectile being pushed out on the fingers of the delivery table so that the carrier moving in the reverse direction can pick it up and carry it over and down to the receiving table. As soon as it rests on the fingers of the receiving table, it has, of course, to be rolled back on this table. If this is not done, the next carrier as it descends will be caught on this projectile and trouble may result.

In order to avoid such trouble, the mechanism of the winch of the hoists is so made that though the hoists may be operated for raising projectiles either by electricity or by hand, they can be used by hand only in the reverse direction for lowering projectiles. The lowering by hand is, of course, quite slow; the men operating the handle are close to the receiving table of the hoist and are easily able to look out and see that the projectiles are moved out from the fingers of the receiving table as fast as they are delivered there by the descending carriers.

In the early days, as was stated, it was intended that these ammunition hoists should be used, not only for raising projectiles, but also for raising powder, but among the instructions issued for the operation of these hoists was one to the effect that they should never be used for lowering powder, and there was an appliance attached to the frame of the upper sprocket wheel which made it impossible for this to be done excepting by improper manipulation.

The actual powder cartridges are so delicate as not to stand very much handling. Consequently, it is customary at drill not to use actual powder cartridges, but to use dummies of essentially the same size and shape. These, of course, can stand more or less rough handling, but in order that the detachment might not get in the habit of sending these dummies back to the magazines by the hoists, and later inadvertently do the same thing with actual powder cartridges, the attachment mentioned was added to the hoist so as to prevent the powder dummies, which are of somewhat greater diameter than the projectiles, from being sent backward over the sprocket wheel.

The development of special powder hoists was made several years after the introduction of projectile hoists, and only after several occurrences had shown the danger of using the same hoist for powder and projectiles. When the design of these powder hoists was undertaken, some method of getting the powder back to the magazine was considered desirable. Consequently, several of the types of powder hoists were provided with chutes by means of which dummy cartridges, and for that matter genuine cartridges also, could, if desired, be returned to the magazine. A rough outline of such a chute is shown on sheet 3 of the drawings accompanying mimeograph 109.

CHAPTER VI.

BATTERIES AND EMPLACEMENTS, GENERAL DESIGN.

In its most common use in connection with military matters the word "battery" is a tactical expression and means a complete Artillery unit. In Field Artillery the battery consists of the officers, enlisted men, horses, a definite number of guns, and the equipment pertaining thereto. In fixed Artillery, of course, the horses are omitted and the battery, considered as a personnel unit, is not in all cases definitely assigned to any particular guns.

By extension, the term "battery" is frequently applied to a group of guns mounted in emplacements which are so located as to form a convenient tactical unit.

Unfortunately, in assigning troops to guns mounted in fixed emplacements, the battery considered as a personnel unit has not always been assigned so as to accord with the battery considered as a group of guns. Usually this has been done, but occasionally a battery (personnel) has been assigned to two or more batteries of guns, and less often, two or more batteries (personnel) have been assigned a single battery of guns.

The word "emplacement" is a structural term only and refers to so much of a battery (of guns) as pertains to any one gun; that is, the gun block, loading platform, parapet, magazines, storerooms, etc.

Since, with smaller guns, the battery usually consists of more than one gun, an emplacement is generally part of a battery. Occasionally, however, especially where the gun is a very large one, the battery consists of but a single emplacement, and in such a case the term "battery" may be used structurally as essentially synonymous with the term "emplacement."

In designing an emplacement it is desirable that it should be known in advance whether or not the gun to be mounted therein is to form a tactical battery of itself, or is to be united with another gun or group of guns to form a tactical battery, because the best arrangement of observation stations, plotting rooms, the duct systems, speaking-tube communications, and other matters connected with fire control depends upon this fact.

Occasionally what is structurally a single battery, designed to be so used tactically, has for tactical reasons arising subsequently been subdivided into smaller batteries. Thus, at the time of or prior to the Spanish War it was customary to consider 16 mortars as forming a tactical unit and, consequently, the mortar batteries then started were designed with this understanding. Since that time tactical reasons have required these older batteries to be divided tactically into two batteries of eight mortars each, and this in turn has required quite a number of changes in the provision for the fire-control system, etc.

EMPLACEMENTS.

The principal purpose of a gun emplacement is to provide a firm and unyielding support for the gun and carriage and convenient platforms and passageways for the personnel, so that the gun may be loaded, manipulated, and fired with the greatest amount of ease and the maximum speed possible. It should also give to the armament and to the personnel as much protection as may be possible from the fire of the enemy and from the action of the elements. It should provide a safe and convenient storage place for the ammunition and other supplies pertaining to the gun, and should, to such an extent as may be possible, provide for the comfort and convenience of the personnel.

It is evident that in its general characteristics an emplacement must be a compromise. For instance, we can make the parapet of the emplacement sufficiently thick and sufficiently high to furnish complete protection to the personnel, armament, and ammunition, but this can be done only by sacrificing the usefulness of the gun by reducing the field of fire. Furthermore, it has generally been found that, as we increase the thickness of the walls, and therefore the protection afforded to the magazines against the enemy's fire, we increase the difficulties due to condensation of moisture.

Perhaps more important still, the question of cost must always be considered. The appropriations applicable to the construction of gun emplacements have always been and probably always will be small, and the necessity of getting as much as possible out of every dollar requires that we seek general efficiency rather than absolute perfection in any one detail. Consequently, in designing an emplacement all the functions that it must fulfill must receive consideration and undue attention may not be given any one function.

Types of Emplacements.

The general character and type of an emplacement necessarily varies greatly according to the size of the gun to be mounted therein, the type of carriage upon which the gun is to be mounted, the character of fire which it is expected to bring to bear upon the enemy, and the extent of the field of fire.

In designing the details of any gun emplacement it must always be remembered that the emplacement is intended to provide rapid and efficient service for the gun and that the gun is not merely an excuse for the existence of the emplacement. Consequently, all of the details of an emplacement must be given careful consideration and must be so designed as to make the service of the gun as rapid, as easy, and as efficient as possible. Unfortunately, it has frequently occurred in the past that the designers of a gun carriage have made no effort to keep in view the engineering requirements of the emplacement and have introduced features which gave considerable trouble to the Engineer Department, even where, with slight modifications which would have served the ordnance requirements equally well, other features could have been used which were much better adapted to the engineering needs. Fortunately, in more recent times this trouble has to a great extent been avoided by a closer liaison between the proper branches of the Offices of the Chief of Engineers and the Chief of Ordnance.

The Ordnance Department prepares the drawings of the gun carriages and of the guns and it is for the Engineer Department to make its designs of gun emplacements conform to the gun carriages designed by the Ordnance Department. Under present arrangements, before the Ordnance Department definitely decides upon the more important details of the gun carriages which may affect the engineering features, the Chief of Ordnance usually sends to the Chief of Engineers prints of these designs in a preliminary shape. These preliminary drawings are criticised in the Office of the Chief of Engineers and, in a number of cases, modifications in the Ordnance drawings have been made at the request of the Engineer Department.

The Engineer Department has been called upon in recent times to provide emplacements for guns less than 3-inch in caliber, for 3, 4, 4.7, 5, 6, 8, 10, 12, 14, and 16 inch guns. These guns have been mounted on carriages of several different types which may be classified as follows: Portable mounts, barbette mounts, masking mounts, disappearing mounts, antiaircraft mounts, mortar mounts, gun-lift mounts, turret mounts, and railroad mounts. The emplacements which are built by the Engineer Department must, of course, be suited to the type of carriage on which the guns are to be mounted.

All of these terms designating the types of gun carriages explain themselves except perhaps the masking mount. This was a modification of the barbette mount, formerly used for comparatively small guns only—that is, guns up to and including the 5-inch. The gun was attached to the top of a pillar operating in a well. When the gun was to be fired this pillar was raised and locked in the elevated position. The gun was then operated essentially as if it were on a barbette mount. When, however, the gun was not in use, the pillar could be lowered into the well, at the same time raising a counterweight, and the gun would drop down into a niche in the parapet and would be hidden from sight.

This gun was thus supposed to unite the advantages of concealment and protection which pertain to the disappearing mount, and the advantages of rapidity and ease of fire pertaining to the barbette mount. Quite a number of emplacements of this character were built and the guns were mounted therein. Theoretically this plan should have worked well and if it had, it would have been extremely useful. Apparently, however, insuperable mechanical difficulties seem to have developed in this type of carriage, and consequently it was thought well to do away with its use. Later, the emplacements which had already been built for the balanced pillar mount were altered for the regular barbette or, as it is sometimes called, the "pedestal" mount.

For the portable mounts, which have heretofore been applied to very small guns only, all that has been provided is a smooth platform upon which the wheels might roll, sometimes with a low parapet in front and sometimes without. Occasionally, ring bolts have been inserted in the platform so that chains could be used to check the extent of recoil.

The emplacements upon which turrets were to be constructed have, up to the present, been built in but one place, Manila Bay. The design of the turrets was briefly discussed in a preceding chapter and the emplacements were so special as to require, for a full understanding, a study of the drawings. They will, therefore, not be further discussion here.

Recently, in connection with field operations abroad, railroad mounts have been successfully developed for guns of comparatively large size and such guns and mounts will doubtless be used in the future in seacoast defense. The idea, however, is only in its infancy and the character of emplacements which the Engineer Department may have to build for these guns has not yet been decided, so it is not possible to discuss the matter further here.

The batteries built for mortars are so different in their general characteristics from those built for direct fire guns that the subject will be treated separately in Chapter VIII.

The general types and characteristics of the emplacements built for the other types of carriages will now be discussed. In this discussion the terms "front" and "rear," "right" and "left" will be used in their strictly military sense; the front of an emplacement being always the part toward the expected position of the enemy; the rear being in the direction away from the enemy; and right and left as they would appear to a man facing the enemy. In this connection it might be well to note that in all drawings of an emplacement or portions of an emplacement, the direction of the enemy should always be toward the top of the drawing.

For convenience in this discussion, the emplacements will be divided into three classes, as follows:

Emplacements for small caliber guns.
Emplacements for medium caliber guns.
Emplacements for large caliber guns.

Under the term "small caliber guns" as here used, will be included those of 5-inch caliber and smaller. The "medium caliber guns" referred to will be the 6-inch gun only. The 8-inch and larger guns will be discussed under the head "large caliber guns."

The reason for including guns up to 5-inch under the terms "small caliber guns" is because the ammunition for all such guns is ordinarily served to them in fixed metallic cartridges containing both the powder and projectile, these cartridges being similar, except as regards size, to the cartridges used in the Infantry rifle. The ammunition service consists merely of carrying the cartridge to the gun and of inserting it in the breech, whence the metallic case is ejected when the gun is fired.

The 6-inch gun is included in a class by itself and called the "medium caliber gun," because, though in the ammunition service of this size of gun the powder and projectile are handled separately as is done in all the larger guns, yet the shell is not too heavy to be picked up and moved by hand. Consequently mechanical appliances for handling the projectiles are not necessary.

For the 8-inch gun and all larger guns, the projectiles are too heavy for easy hand manipulation and mechanical appliances are, therefore, necessary.

EMPLACEMENTS FOR SMALL CALIBER GUNS.

The emplacements which have been built by the Engineer Department for guns of smaller caliber than 3-inch have, as a rule, consisted merely of a gun block sufficiently large and sufficiently heavy to hold the gun securely when it is fired and no discussion of such emplacements would appear to be necessary.

This has also been practically true of the emplacements built for the 3-inch antiaircraft rifles heretofore furnished by the Ordnance Department, the gun block for this gun, however, requiring the construction in it of a shallow gun-well.

Most of the small caliber guns which have had to be regularly emplaced have been the 3-inch, 4.7-inch, and the 5-inch guns. The 4.7 rifles were mainly Armstrong guns purchased by the United States from England during the Spanish War. They were about as powerful as the standard 5-inch guns then in use in the United States, and consequently the emplacements built for them were essentially similar to the standard 5-inch emplacements and no further description is necessary here.

The Board of Engineers' type plans for 3-inch emplacements were published in Mimeograph 30 and its various supplements and for the 5-inch emplacements in mimeographs 16, 18, and 33. Outline drawings showing the more important details of the most characteristic of these designs have been prepared and accompany these notes as Plates III, IV, V, VI, and VII.

Plate III shows what is known as the 1898 type of 3-inch emplacement designed for 3-inch guns on balanced pillar or masking mounts; Place IV shows the 1902 type of 3-inch emplacement for 3-inch guns on pedestal mounts; and Plate VII, the 1899 type of 5-inch emplacement for 5-inch guns on pedestal mounts. In their essentials, these types are exceedingly similar. In all of them, the emplacement consists of but little more than a loading platform, upon which the men stand while loading and firing the gun, and of a magazine. In front of the emplacement there is a low parapet about 3 feet high which gives some protection to the personnel, additional protection being given by the shields with which such guns are usually provided. The crest of this parapet over which the gun is fired is on the same level as the top of the roof of the magazine. Consequently the floor of the magazine has to be some 10 feet or so below the loading platform level. The magazines provided for the 5-inch guns are 13 by 22 feet and for the 3-inch guns 9 by 15 feet. About 7 or 8 feet of head room is allowed in the magazine, the ceilings of which are of concrete from 5 to 7 feet thick. The roof over the magazine, when viewed from a distance, forms with the crest of the parapet a practically unbroken horizontal line.

The low parapet in front of the loading platform, except occasionally in the center emplacements of batteries consisting of more than two guns, is built in the arc of a circle, the radius of which is about 7½ feet in the 3-inch emplacements and about 11 feet in the 5-inch emplacements. Behind the gun the loading platform extends horizontally backward, for a distance about equal to the radius of the front circle, to the top of a flight of from six to eight steps leading directly to the rear and down to an intermediate or terreplein level, some 7 feet or so below the crest of the parapet. From the platform of this intermediate level another flight of steps runs downward parallel to the front of the battery to near the door of the magazine.

The ammunition for these guns is fixed, consisting of a metallic cartridge loaded with powder and clamping the base of the projectile, similar, except as to size, to the cartridge for the Infantry rifle. This ammunition is furnished by the Ordnance Department in boxes containing several cartridges. The method of ammunition service proposed is that these boxes shall be broken open in the magazine, and individual cartridges shall then be carried by hand out of the magazine door and up the two short flights of steps to the detachment around the gun. In order to make it possible to keep a few rounds of ammunition close to the gun in case of emergency, ammunition recesses, ammunition shelves, or platforms are usually provided on the sides of the loading platform. Such recesses are shown on Plates III and VI and the platforms on Plate VII.

Plate VI shows designs prepared in 1897 by the Board of Engineers for emplacements for 5-inch guns mounted on balanced pillar mounts. While in general similar to the 5-inch emplacement described above (Plate VII), the loading platform differs in important particulars. The concrete part of this platform was nearly 7 feet below the crest of the parapet and the loading platform proper consisted of a metal platform attached to the gun carriage, which rose when the gun was lifted into the firing position. The loading detachment, of course, stood on this metal platform and the ammunition was handed up to them by members of the detachment standing on the concrete platform below.

In the emplacements built for guns on balanced pillar or masking mounts, gun-wells were necessary and niches were left in the sides of the walls of the emplacements, into which the gun could be lowered when it was not in use. In this position it was, of course, hidden from the sight of the enemy, and the top of the battery as viewed from the front consisted of a practically unbroken horizontal line, giving no indication of the position of the gun. The balanced pillar mount was later abandoned by the Ordnance Department and all emplacements built for such mounts were altered so as to be suitable for the pedestal or regular barbette mount.

The early emplacements consisted of but little more than the magazine, the loading platform, and the stairway between. In a few cases, however, observation stations or crow's nests were built on a flank of the battery (see Plates III, VI, and VII) and under this crow's nest a small bomb-proof relocating or plotting room was provided. Plate IV shows the addition of small storerooms under the stairways.

In most cases, the 5-inch guns were mounted in individual emplacements, but occasionally they were grouped into batteries of two or three guns each. The 3-inch guns were usually grouped either into batteries of two guns or four guns, individual emplacements being practically never used. When the guns were grouped into batteries, the 5-inch emplacements were intended to be about 45 feet apart, gun center to gun center, and the 3-inch guns about 29 feet.

When the attempt was made to man at the same time all the 3-inch guns of a battery, it was soon found that difficulties were met with due to the effect of the blast of one gun upon the detachment at the next. A gun could be fired directly to the front without any discomfort to the detachment at the next gun, but if it was fired at any material angle of traverse from the capital the blast effect soon became so great that the men could not stay at the next gun, consequently it was evident that in future batteries the guns should be placed farther apart.

The first attempt to do this is shown on Plate IV. The designs shown in this plate, sometimes called the 1902 type of 3-inch emplacement, are for a two-gun battery having both magazines between the guns. This separates the gun centers to an interval of 42 feet. Otherwise, the design resembles closely the 1898 type. (Plate III.)

A more efficient attempt to avoid the trouble from blast was described in 1903 in the sixth supplement to mimeograph 30. (See Plate V.) The guns are shown as spread farther apart, 62 feet center to center and, in order to still further diminish the effect of the blast of one gun upon the men at the other, the roof of the magazine between the guns is shown as rising in a gently rounded mound of earth, the crest of which, at the center, is about 7 feet above the loading platforms. Both magazines are located in the traverse between the guns, and they are made 12½ by 22 feet, a considerable increase in size over the plans of the older 3-inch emplacements. Furthermore, since the magazines did not fill up all the space between the guns, a storeroom 10 by 12 feet is provided between the magazines.

For convenience in ammunition service the stairway leading from the magazine level to the loading platform is broken into two additional levels. The intention was that the boxes containing several rounds of ammunition should be brought by hand from the magazines and should be lifted up and placed on the lower of these two additional levels. There the boxes were to be broken open, the individual cartridges being handed to men on the next level who placed them on shelves provided on that level for that purpose. From these shelves the cartridges were to be handed to members of the loading detachment at the gun.

In order to provide space for the members of the detachment on these different levels, the stairway leading down from the loading platform was made only about 3 feet wide.

Since these plans were published in 1903, a large number of 3-inch emplacements based on them have been constructed, the guns in all cases being mounted in pairs. In a few of the more recent batteries, however, improvements have been made in the ammunition service. A niche about 2 by 5 feet and high enough for a man to stand in has been left in the rear corner of the magazine wall on the side toward the gun, the bottom of the niche being about 2 feet above the floor of the magazine. Between the upper part of this niche and the shelf on the upper level behind the loading platform an opening was left so that a man standing in the niche can push the cartridges by hand directly out on to the ammunition shelf. When this was done the lower of the two additional levels was omitted and the stairs leading downward from the loading platform were moved to the outer flank. (The location and general outline of the niche are shown dotted on the rear elevation on Plate V.)

It will be noted that the protection given the magazine, as shown in all these plates, consists of about from 6 to 8 feet of concrete and of about from 20 to 24 feet of sand. This was estimated to be sufficient to protect these guns against a 6-inch projectile.

No arrangements for the prevention of condensation are shown in any of the drawings, this being a detail left to the constructing officer. In actual construction many of the emplacements had built into the magazine walls, a foot or so from the interior surface of these walls, vertical tiers of porous tiles.

About 1909 another important change was made in the last type of emplacements—a battery commander's station being added above the rear of the traverse. This was usually built with concrete walls about 4 feet high, over which was placed a light corrugated iron roof with observation slots in front and on the sides. Above the roof were placed boards facing the guns, on which data as to the range of the target could be displayed. Part of the side and rear edges of the earth fill over the traverse was removed so as to provide walkways from the loading platforms to the battery commander's station.

TWO MAIN TYPES OF MEDIUM AND LARGE CALIBER EMPLACEMENT.

Before going further into the detailed discussion of emplacements for 6-inch and larger guns, it would appear well to distinguish between the two essentially different types in accordance with either of which these emplacements may be designed.

These two types are sometimes called respectively the "two story" and the "one story" types, and sometimes they are designated as the "horizontal crest type" and the "horizontal ammunition service type."

In the earthern emplacements constructed during and just after the Civil War, the guns were mounted on barbette carriages and were, therefore, always visible. In order to obtain a sufficient volume of fire they were mounted fairly close together along a parapet, although it was customary, wherever infilade fire was feared, to place frequent traverses in the line of guns so as to reduce the effect of this enfilade fire. In general, the guns were emplaced in pairs, two guns in the interval between two traverses.

These traverses extended high above the parapet and, in fact, above the guns and, therefore, were visible from a considerable distance. The guns then in use were mounted in barbette and were always exposed to view, the ranges used at the time were comparatively short, and since the guns themselves were not concealed no concealment was lost by the exposure of the traverses to view.

When, however, the disappearing principle was introduced into seacoast gun carriages so that the gun in the loading position was entirely out of sight, it became desirable to conceal, if possible, the position of the gun. It appeared to be desirable to reduce the height of the traverse to that of the parapet, so that when seen from the front, the emplacement appeared with an unbroken horizontal crest, no guns being visible and no traverses indicating the approximate positions of the guns. The early designs for disappearing emplacements as prepared by the Board of Engineers were all based on this idea.

Unfortunately, in attempting to keep this unbroken horizontal crest one great disadvantage was introduced, that is, the lowering of the magazines far below the level of the gun in the loading position.

The Ordnance Department's designs for disappearing carriages place the loading platform, upon which are moved the ammunition trucks bringing projectiles to the guns, from 9 to 11 feet below the crest of the parapet in front of the gun. The larger of these figures is just about the thickness of concrete considered necessary for the roofs over the magazines and, consequently, in this type of emplacement, the ceilings of the magazines could not be higher and usually must be lower than the pavements of the loading platform. When it is considered that in all the magazines considerable head room is necessary, especially in the shell rooms where trolley rails are required for moving projectiles, it will be seen that if the horizontal crest is to be maintained, the floors of the magazines are pushed down far below the loading platform level and there results a two-story type of emplacement, a lower or first story containing the powder and shell rooms, and a second or upper story with the floor upon the loading platform level.

In service the ammunition must, of course, be raised from the magazine level to the loading platform level. In small emplacements (that is, for 5-inch or smaller guns) where the ammunition is handled by hand, this difference of level is not so important and in the 6-inch emplacements not of great importance, but in the larger emplacements where the projectiles are too large and heavy for hand manipulation and where, therefore, mechanical means are necessary for raising them complications necessarily ensue. In the first emplacements constructed the hoists for raising ammunition were somewhat crude, but they were soon improved until they became mechanically almost perfect. Nevertheless, the necessity for using hoists was one which it was desired to avoid if possible.

It was therefore suggested as possibly desirable that the larger gun emplacements should be designed so as to provide what may be called horizontal ammunition service, the floor of the magazine being essentially on the same level as the loading platform so that no hoists are necessary.

The difference of level between the floors and magazines and the tops of the roofs over them is fixed within small limits by the need of sufficient head room in the magazines and the necessity of providing sufficient cover over them. The difference in level between the loading platform and the crest in front of the gun is also fixed within small limits by the type of gun carriage, and consequently, if the loading platforms and the floors of the magazines are to be placed on essentially the same level, the top of the roofs over the magazines must project far above the crest of the parapet in front of the loading platform. The approximate position of the gun is indicated to the enemy because it must be at about the center of the distance between two traverses and the advantage of concealment obtained with the horizontal crest type of battery is lost.

In other words, in designing an emplacement we can obtain horizontal ammunition service or we can obtain a horizontal crest, but we can not obtain both. We can build a disappearing battery to provide concealment of the location of the gun or we can build a battery so as to provide the easiest form of ammunition service, but we can not build a battery which will provide both of these ad vantages.

The horizontal-crest type of battery means a two-story type, and is sometimes referred to as such. With the type of battery providing horizontal ammunition service the battery is essentially on one story and it is therefore sometimes called the one-story type of battery.

In the discussion above these two types of battery have been considered as if the two types were found in the emplacements for heavy guns only, because in emplacements for heavy guns the two types are most distinct, one requiring and the other not requiring ammunition hoists. However, the same distinction may be made if desired in the batteries for small caliber guns. Thus the original design for balanced pillar or masking mounts was based upon the horizontal-crest idea, the guns when lowered to their niches being hidden from sight and there being therefore nothing to make a break in the evenness of the crest. The magazines were likewise on a lower level and the emplacements were therefore essentially of the two-story type.

For guns with masking mounts the horizontal crest type of battery provided a complete concealment of the position of the gun, but with the pedestal type of barbette guns no such concealment was possible because the gun was always in sight. Consequently in preparing the 1903 design for emplacing the 3-inch pedestal guns (see Plate V) no attempt was made to adhere to the horizontal crest, the top of the traverse between the guns rising in a gently rounded surface a considerable distance above the crest of the parapet in front of the gun. However, the magazine is kept just as low as it was in the former type of 3-inch emplacement, so that this type of design combines neither the advantage of the horizontal crest providing concealment nor of horizontal ammunition service. The horizontal crest was not necessary because the guns were in barbette and horizontal ammunition service was not considered necessary because the ammunition was not heavy. Keeping the magazines low increased the angle of traverse over which the guns could be fired.

EMPLACEMENTS FOR MEDIUM CALIBER GUNS.

ix-Inch Emplacements.

The designs prepared by the Board of Engineers for 6-inch emplacements were published in Mimeographs 31, 40, and 59. Plate VIII shows in outline the designs of 6-inch emplacements prepared by the Board of Engineers in 1900 for guns on pedestal mounts with shields. These designs were subsequently published in mimeograph No. 40.

The drawings showed a 2-gun battery of the 2-story type, the lower story containing two shell rooms, one for each gun, a magazine for the joint use of both guns, and a room for general use marked on the drawing as the "guard room." The upper story is on two levels, one about 4½ feet higher than the other. The uppermost level consists of the gun or loading platforms on which are located the pedestals of the two guns 20 feet apart, center to center. In front of the gun is a low parapet about 2½ feet high. The lower level of the upper story is called the "terreplein" and is connected with the upper level by a broad flight of steps. At the center of this terreplein level there is a "powder recess" in which there can be placed temporarily a few charges of powder available for instantaneous use. At both flanks of the terreplein level and immediately over the shell rooms of the lower story are the openings of the shell hoists. From the extreme sides of this terreplein level there are shown two ramps running down to the level of the lower story. For more convenient communication between the two stories a double stairway is placed in the rear of the center of the battery leading from the lower story up to the terreplein.

The powder service was intended to be by hand, the cartridges were to be picked up from the magazine and carried out through the entrance to the shell room to the rear stairs, up the stairs, and thence direct to the gun or to the powder recess. The projectiles could be carried by hand over the same route as the powder, or they could be raised by means of hand operated mechanical shell hoists from the receiving tables in the centers of the shell rooms up to the delivery tables on the terreplein level. The design of the receiving tables was quite complex. It was described in the chapter on ammunition supply and service and is illustrated in outline in figures 3 and 4 of Plate II.

In preparing designs for these emplacements the idea of reducing condensation was evidently kept in mind as there is shown a 6-inch air space built around the walls in front of the magazine and on the inner sides of the shell room; while at the rear numerous doors and windows were provided which when left open should provide fairly efficient ventilation. Unfortunately, however, the air space has no exterior openings and ends in the tile facing in front of the battery. It was therefore what may be called a blind air space. The necessity for this air space will be more fully discussed in the chapter on dryness, etc.

The designs shown have several disadvantages; first, the guns are placed so close to each other that if either be fired at any considerable angle of traverse from the capital the blast from the gun will certainly interfere with the detachment at the other gun. Furthermore, the guns are so close together that an enemy's shell striking in the immediate vicinity of one will almost certainly put the other out of action also. The disadvantages arising from this close spacing of the guns were noticed very shortly after the issuance of the mimeograph and the first officer called upon to design an actual battery, based upon the mimeograph, suggested a change to what may be called the "Montgomery or 1901 type." (See Pl. IX.)

In this latter type the guns are separated by a distance of 52 feet which gives considerable protection to the detachment at one gun from the blast of the other. The arrangement of the lower floor also is quite different. The two shell rooms are drawn from the flank toward the center where they are united into a single shell room, each gun, however, being provided with a separate hoist. The powder magazine is placed in the center of the battery in front of the shell room. The room for general use, disignated as a "guard room" in the old design, has been broken into two and these have been placed on the flanks of the shell room. As in the other design, there is a double stairway in the rear of the battery, but instead of the tops of the stairways being in the center and the feet outward, the feet of the stairways are placed one on either side of the center door of the shell room and the tops are spread out to the flanks in rear of the guns.

As in the other design, the upper story has two levels, the terreplein level and the gun platform level. On the terreplein level, instead of the single center powder recess two smaller recesses are provided, one in rear of each gun. The projectile hoists, instead of delivering the projectiles on delivery tables on the terreplein level, are now so fixed as to roll the projectiles out on the floors of the gun platform levels in rear of and not far from the guns. On the gun platform level at the center of the battery, a crow's nest or battery commander's station is provided.

In the drawings no special arrangement for preventing condensation is shown, but in the actual construction of the only battery built on these plans a layer of tiles was built in the magazine walls. However, this battery is so small and so many doors and windows are provided on its rear that when these doors and windows have been kept open there has almost never been any condensation.

The protection given the shell rooms in Plate VIII and the magazines in Plate IX consists of about 6 feet of concrete and 22 feet of earth, sufficient, it was calculated, to more than keep out the 6-inch projectiles of the day.

In 1902, the Board of Engineers prepared new type plans for 6-inch barbette guns which were published as a second supplement to Mimeograph No. 40 and the general outlines of which are shown on Plate X. The type of emplacement shown differs from all the plans discussed heretofore in that it is essentially of the one-story type and provides what may be called "horizontal ammunition service." The guns are separated by an interval of 94 feet and between them is the magazine, built in a high traverse, which rises at its center some 20 feet above the floor of the magazine and some 13 feet above the level of the loading platform around the guns—these platforms being approximately 7 feet higher than the floors of the magazines.

The pedestals of the guns are located near the centers of wide, gently-sloping loading platforms, nearly 24 feet in diameter. In front these loading platforms are partially protected by a low parapet about 2 feet high, and to the rear they are partially surrounded by a so-called "banquette" some 3 feet wide and on a level about 3½ feet lower. About 20 inches below the banquette is the truck platform which slopes very gently to the rear and toward the traverse down to the level of the floor of the magazine, the slopes not being too steep for the easy rolling of trucks loaded with powder or projectiles.

For ammunition service the Ordnance Department was to provide small cars or trucks which would hold several complete charges. These trucks were to be loaded inside the magazines and were then to be pushed along the floor of the magazine and of the truck platform until they were close to the banquette and in rear of the gun in whichever direction it might be pointed. Members of the detachment standing on the banquette were then to lift the powder and projectiles from the truck and hand them to other members of the detachment on the loading platform, who would carry them to the gun.

The traverse was quite large and roomy. It contained a powder room about 12 by 35 feet for the common use of both guns, and a shell room about 12 by 38 feet, likewise for both guns. Four other rooms for general use were provided, each being designated for some supposed particular use, as shown on the plan. At the rear of the top of the traverse there is shown a battery commander's station reached by a double flight of stairs.

No special arrangements for preventing condensation are shown in these drawings, the details being left to the commanding officer.

These plans were the first to indicate an earthen blanket over the concrete roof of the magazine, but as this is clearly shown on the drawing no further description of it is necessary.

About the time that the designs just discussed were published, the Ordnance Department succeeded in perfecting the details of the 6-inch disappearing carriage and the Board of Engineers at once proceeded to prepare a typical design for emplacements for these carriages. These, the 1903 type plans, were subsequently published in Mimeograph 59 and the main details are shown on Plate XI.

As will be noted by comparing Plates X and XI, these new designs for the disappearing emplacements are very similar to those of the barbette emplacements, both containing the high center traverse and being of the one-story type. The principal differences are: The provision in the disappearing plans of much wider loading platforms extending out more than 27 feet from the centers of the gunwells and the provision of a powder passage connecting the front of the two loading platforms and extending from side to side of the traverse immediately in front of the powder magazine. Doors are cut from the powder magazine into this powder passage which thus serves not only to permit more efficient ventilation for the powder magazines but also to provide a protected passageway for powder service which is thus made distinct from the projectile service.

The widening of the loading platforms makes it necessary to separate the guns about 125 feet, approximately 31 feet more than in the barbette plans, and the use of the disappearing principle permits the parapet to be raised to some 7 feet above the loading platform. The loading platform, itself, was lowered until it is about 5 feet only above the level of the magazine floor instead of 7 feet, as in the barbette emplacements. This permits a very great reduction in the slope of the truck platform floor, which is now made almost level.

With the exception of the introduction of the powder passage which has been mentioned, the traverse is essentially similar to that of the barbette design.

After the publication of the two mimeographs mentioned but few modifications were made in 6-inch emplacement designs for a period of some 9 or 10 years, during which time many batteries were built in various sections of the country, based on these standard plans, In a few places no provisions for preventing condensation were made, reliance being placed upon the ventilation of the battery which the wide powder passage rendered easy; in others, as at Fort Wool, Va., the walls and ceilings of the shell rooms and powder rooms were faced with tiles and an air space was left between the wall tiles and the wall proper.

In some of the batteries following this general design the traverse was altered considerably, the rooms marked "Storeroom" and "Storage battery room" were omitted and the "Guard room" and "Office" were merged into a single room about 10 feet measured fore and aft, and about 22 feet measured across the battery. This reduced the depth of the traverse by about 10 feet. In batteries thus modified, which were seriously exposed to flank fire from either side, the entrance to the traverse from the loading platform on the exposed side was made at the rear of the traverse and not on the side, as shown in the plates.

The magazine protection shown is about 11 feet of concrete and, in the center, about 10 feet of sand—sufficient to withstand the 6-inch projectile of 1902 or 1903.

Although not shown on the plates, recesses were usually provided in the side walls of the emplacement for telephone booths, for storing sponge and rammer staves, and for other miscellaneous purposes.

About 1912 plans were prepared for the 6-inch emplacements for the defenses of the Panama Canal. These differed considerably from the plans just discussed and are shown in general outline on Plate XII.

As will be noted by a comparison of the drawings, the same general arrangement of guns and magazine traverse is retained. The battery is of the one-story type and practically horizontal ammunition service is provided.

The most striking differences between the Panama and previous designs are the great thickening of the earth blanket over the concrete roof of the magazine, which thus raises the top of the traverse much higher, the provision of gentle sand slopes on the sides of the loading platform instead of the concrete walls of the old designs, and the placing of the entrance to the shell room in rear of the traverse instead of on the side, thus making the entrance of an enemy's projectile much less probable.

Another quite important difference is the omission of the banquette level, the truck platform being raised up to and merged with the loading platform. The difference between the level of the floor of the shell room and that of the loading platform immediately around the gunwell steps is made about 3 feet, and the distance between the magazine and the gun is sufficient to permit this change in level to be made by a pavement having a grade of less than 3 per cent, up which the loaded trucks can be easily pushed.

The guns are shown as separated by a distance of 175 feet, the increase being necessitated by the space required for the sand side slopes.

The same arrangement of having a shell room and powder room common to both guns is retained and the powder passage likewise is retained, but, in order to increase the overhead protection of the powder room, its floor has been lowered about 3 feet below the floor of the shell room, convenient stairs being provided between the two. The powder passage likewise is lowered, so that additional stairs are required between it and the loading platform.

The center traverse is shown as having in the rear of the shell room a plotting room, surmounted by a battery commander's station, and connected by range indication tunnels with indicating boards on the left side of the loading platforms. Rooms for the comfort of the officers and enlisted men also were provided as shown.

As will be noted, also, no special provisions are made for preventing condensation, such provisions being unnecessary, since the batteries were built in the Tropics, where the temperature remains practically the same all the year round, and where, therefore, there is practically no condensation.

As it so happens that most of the 6-inch Panama batteries are built in fairly close proximity to emplacements for large guns and, therefore, may presumably be struck by large projectiles aimed at the emplacements of the large guns, it was considered essential that the magazines of these 6-inch guns be given the same amount of protection as the magazines of the large guns. In most cases, also, one flank of the battery was considered much more exposed than the other and was, therefore, given slightly increased protection.

All but two of the 6-inch guns which have been emplaced at Panama having been provided by the Ordnance Department with disappearing carriages, it was not considered necessary to prepare any typical 6-inch barbette plans. Only one such battery was built in the Panama defenses and its design was based upon the Montgomery, or 1901, type. Many modifications, however, were required by local conditions and the necessity of providing dormitories and other arrangements for the comfort of the garrison. The designs of this battery, therefore, are quite special and will not be further discussed here as the plans themselves will doubtless be available for any officer who may desire to examine them.

LARGE-CALIBER EMPLACEMENTS.

When about 1890 emplacement construction was resumed in this country, it was the policy of the War Department, based upon the recommendations of the Endicott Board, that in general all large-caliber guns should be mounted on disappearing carriages. Barbette mounts were to be used in a few special locations only, such as where the available sites were very high. Consequently, no type plans for large-caliber barbette emplacements were prepared.

Owing, however, to the delay in manufacturing satisfactory disappearing carriages and to the excitement preceding and incident to the Spanish War, quite a number of 8-inch guns and some 10-inch and 12-inch guns were actually mounted in barbette, and the work was in many cases hurriedly done.

The 8-inch guns which were so mounted were usually located in some older fortifications. The carriages were placed on flat concrete platforms into which the bolts for holding down the base ring were inserted. In many cases the magazines already in existence were utilized; in others, special magazines were built. In either case, the ammunition service consisted essentially of rolling the projectile and powder on trucks to the vicinity of the gun. There the projectile was picked up by a crane attached to the rear platform which formed part of the gun carriage.

The barbette emplacements constructed for 10 and 12 inch guns were usually designed, as far as might be applicable, upon the then standard type of two-story disappearing emplacements, the magazines and shell rooms being in a lower story and hoists being used to lift the ammunition up to the platform on which the base ring stood, which was usually about from 5 to 8 feet below the crest of the parapet. The ammunition was raised to the platform by means of the hoist and was then rolled in a truck to near the breech of the gun. Here the projectile was picked up by a crane mounted on the steel breech platform attached to and forming part of the gun carriage.

These barbette batteries varied considerably as regards these details and since no one type was ever developed into what may be called a standard, and no others like them will ever be built, a further discussion here appears unnecessary.

Gun Lift Battery.

The first emplacements built for heavy guns so they might disappear from sight while being loaded was the large gun-lift battery built at Sandy Hook in the early nineties. This battery was built for two 12-inch guns. Each gun and its carriage was mounted on a heavy metal platform. When loaded and ready to fire, the entire platform with the gun and carriage was raised from below by hydraulic pressure until it had reached the proper level. After the gun was fired it was lowered until it disappeared from sight behind a parapet. The gun was then loaded from covered chambers in the rear.

Although in a limited sense a mechanical success, at least to the extent that the gun worked properly and could be used, this battery was nevertheless exceedingly slow in action, firing one shot from each gun every five minutes. Furthermore, it was a very expensive installation and no more batteries of this type were ever started. Some years later the original battery was abandoned.

Disappearing Emplacements.

The first of the standard Crozier disappearing carriages to be perfected was the 8-inch. This was very shortly followed by the 10-inch and not long afterwards by the 12-inch. By 1894, the Board of Engineers had prepared typical plans for the 8-inch and 10-inch disappearing emplacements. A few years later they prepared other and improved type plans for the 8-inch, 10-inch, and 12-inch emplacements. Subsequently, about 1902 and 1903, new and quite different type plans were published for the 10-inch emplacement and a short time later, for the 12-inch. Since, however, each particular type of 10-inch disappearing emplacement differed from the corresponding types of the 8-inch and 12-inch in dimensions only, the discussion here will be restricted mainly to a description of the 10-inch emplacement with incidental reference to special details embodied in the 12-inch designs. The 8-inch emplacement designs have been published with mimeographs 8 and 25 and their supplements; the 10-inch emplacement designs, with mimeographs 8, 22, and 36, and their supplements; the 12-inch emplacement designs, with Mimeographs 8, 24, 66, and supplements; and the 14-inch emplacement designs with mimeograph 109.

1894 Types of Disappearing Emplacements.

The first type of disappearing emplacement for large-caliber guns is what may be called the 1894 type. On Plate XIII there is an outline drawing showing the most complete form of this type of emplacement, this drawing being taken from the original drawing of a battery constructed at Fort Monroe, Va., in 1894. It is interesting as showing the narrow loading platforms and crude character of ammunition service provided, as well as the contracted and inadequate magazine space and the total lack of provision for keeping the magazines dry.

The guns are separated by an interval of 124 feet and are located behind a high, thick parapet finished on the top with a strictly horizontal crest. Immediately in front of each gun the line of the parapet is slightly hollowed out and in rear of the gun is a raised structure intended to be used as a loading platform. The magazines are located to the right of their respective guns in ill-defined traverses which do not rise above the crest of the parapet.

The general type is the one which afterwards grew into the standard two-story emplacement, but in these first designs the two stories were not well defined—instead there were several different levels.

First and lowest, there was the magazine level on which were the powder magazine and shell room, an entrance gallery, and the bottom of the hoist well, all with their floors at the same general elevation, about 24 feet below the crest of the parapet. Next there was what may be called the crane level, because upon it were placed the bases of the cranes used for lifting the projectiles up to the loading platform. The floor of this level was not, however, strictly horizontal; in front it was about 7 feet above the magazine floor, but it had quite a slope downward and to the rear so that as it passed around behind the room under the loading platform it was about 3 feet lower. At the right-hand front corner of the crane level there was an entrance into the traverse, forming what is sometimes called the lobby. This lobby, at the rear, abutted on the hoist well. The ceiling of the lobby and of the hoist well were at the same elevation and continuous, but there was a difference of 7 feet in the elevation of the floors. Third, there was the working platform level about 3 feet higher than the crane level and extending around the base of the gun carriage. Fourth, there was the loading platform level, approximately 4 feet above the working platform level, 7 feet above the crane level, 14 feet above the magazine level, and about 10 feet below the crest of the parapet. On this level is the comparatively narrow loading platform upon which the men stand while ramming projectiles or powder into the guns.

All the rooms and galleries in the traverse were made with their ceilings in the form of full center arches, furnishing about 8 feet head room at the center. A trolley rail was attached to the ceiling of the shell room and extended out through the gallery to the edge of the hoist well. Another trolley rail, some 7 feet higher, extended fore and aft along the ceiling of the hoist well and along the ceiling of the lobby to the door which opened on the crane level.

The projectile service in this type of battery was somewhat complex and crude. The shell was first to be picked up in the shell room by means of a differential hoist running on the lower trolley rail. The trolley was then to be pushed through the gallery and to the end of the lower trolley rail at the side of the hoist well. Here the projectile was to be lowered to the floor, to be pushed out under the center of the hoist well, and to be picked up by another differential block attached to a trolley running on the upper trolley track. By means of this differential block it was to be raised up until it was slightly higher than the floor of the lobby. This trolley was then to be rolled on the upper trolley track along the ceilings of the hoist well and of the lobby to the doorway on the crane level. Here the projectile was to be again lowered to the ground and rolled to within reach of the crane by which it would be raised up and deposited upon a truck on the loading platform level. This was the normal method of projectile service, at least for handling loaded shell. It was provided, however, that a few solid shot might be stored on the floor of the room under the loading platform. These could be rolled out of one of the doors of this room and picked up by one of the rear cranes which would hoist them up and place them on trucks on the loading platform.

The powder could be handled in much the same way as the projectiles or, preferably, the individual cartridges which were not too large to be carried by one man, would be carried by hand up to the loading platform. For this, however, it should be noted that the conveniences were few. There were no stairways connecting the magazine level with the crane level on the magazine side of the emplacement; consequently, the man with the powder charge coming from the magazine had to walk well to the rear of the emplacement and thence up a ramp to the crane level, then he had to walk well forward and up a flight of stairs to the level of the working platform. Here he had to climb another flight of stairs to the loading platform level. The route of the powder might be somewhat shortened by having the man who picked up a cartridge carry it to another man standing on a stool at the foot of the hoist well who could lift it up and hand it to a third man in the lobby.

In this design there was apparently no deficiency in parapet protection. Immediately in front of the gun the concrete parapet was 20 feet thick with 45 feet of earth in front, while the horizontal protection in front of the magazine measured at the level of the ceiling was not less than 50 feet of concrete with 30 feet of earth in front of that.

A particularly noticeable feature of this design was the utter insufficiency of magazine space and the inadequate size of the loading platform. The powder magazine was but 8 by 16 feet. The shell room was 6 by 16 feet, but the projectile storage space was supplemented by the room under the loading platform, some 3½ feet wide, which was intended to be used for storing solid shot.

The loading platforms stood up quite isolated—they were not connected with each other or with anything else. They could be reached only by the two stairways connecting each with its working platform. The loading platform was only 13 feet wide, which was barely sufficient for handling the projectile truck and left almost no space for the ramming detail. Furthermore, the loading platform was finished off in front by a vertical wall descending 4 feet to the working platform, which made it quite dangerous for the detachment. Handrailings could not be placed here without interfering with the service of the gun, though, of course, they were erected along the rear edge and the ends of the loading platform.

A serious defect in the original design was the small size of the gun well, which was barely large enough to hold the counterweight. Before the gun could be mounted it became necessary to make a hole from the crane level through into the bottom of the gun well in order that the blocking used in mounting the gun and carriage might be withdrawn.

Another noticeable feature was the absence of anything like proper arrangements for ventilation or for prevention of dampness. The only openings into the magazine space were two doorways, and in the early emplacements these doorways were closed with solid doors, so that when they were closed there was no circulation of air at all. Consequently there was much condensation. Furthermore, in all such batteries the concrete was made of Rosendale cement and in practically all cases was so porous as to permit much seepage of water through it. Attempts were made subsequently at the Fort Monroe battery to diminish this seepage by covering the concrete roof of the emplacements with layers of tar or asphalt. These attempts, however, were only partially and very temporarily successful.

Crude though this 1894 design was, yet it is easy to see how it grew into the subsequent two-story type. The crane level was done away with entirely, the floors of the rooms under the loading platforms being lowered to the same level as the floors of the magazine. The loading platform was much enlarged to the front and to the sides, so as to touch the parapet and traverse walls, while to the rear it was extended by a corridor passing along the rear of the magazine traverse and connecting the loading platforms of the two or more emplacements. The loading platform and the working platform were connected by a set of circular steps concentric with the axis of the gun well. The hoist well was enlarged and was fitted for the mechanical hoisting apparatus for lifting the ammunition up to the level of the loading platform.

Subsequent Designs.

Following the 1894 design above described, quite a number of successive plans were prepared by the Board of Engineers, each an improvement upon the preceding. In these successive designs more space was provided for ammunition storage and provisions were made for decreasing the amount of dampness; the loading platforms were widened and were much improved; and, incidentally, a great many improvements were made by the Ordnance Department in the design of the gun carriage.

The ammunition service especially was improved, there being substituted for the cranes, balanced platform hoists, by which the ammunition trucks already loaded with both powder and projectiles could be raised from the floor of the magazine to the loading platform.

Subsequently, improved chain hoists were substituted for these balanced platform hoists.

1896 Type of Disappearing Emplacements.

An outline drawing of the 1896 type of 10-inch disappearing emplacement is shown on Plate XIV and of the 12-inch emplacement on Plate XVIII. By the time these designs were prepared the emplacements had evolved into their typical two-story form, there being a lower story or magazine level and an upper story or loading platform level, while the top of the battery was still finished off in an unbroken horizontal plane. In the 12-inch design, Plate XVIII, the floors of all the rooms of the lower story are at exactly the same elevation, but in the 10-inch design, Plate XIV, the floors of the rooms under the loading platform are shown as being about 3 feet higher than those in the traverse.

The means of communication between the two stories have been somewhat improved over the 1894 type. At the rear of the right side of each loading platform, a wide staircase connects this platform with the lower level and in front of the same side of the loading platform another staircase runs from the working-platform level down to the lower level. These designs are the first to show the wide annular steps connecting the loading and working platforms.

As compared with 1894 type, the loading platform has been much widened and extended. It now extends to the parapet wall in front and to the traverse walls on both sides. The rear of the platform in the 10-inch emplacement is about 32 feet from the axis of the gun well and in the 12-inch it is about 41 feet. Each loading platform has also been extended by means of a so-called "truck corridor," in rear of a portion of the traverse, so as to provide a convenient location for the upper outlet of the ammunition hoist, but the loading platforms are still isolated from each other, the truck corridor not having been extended completely across the traverse between the two emplacements.

The magazine space has been much increased over the 1894 type, as will be seen by a comparison of the size of the powder and shell rooms of the emplacements as shown on Plates XIII and XIV. Those shown on the latter plate have more than twice the floor area of those on the former. Solid shot are still to be stored in the room under the loading platform, which has been much increased in size. The ammunition service has been greatly improved by providing in each emplacement four hoists wells for the use of four differential blocks, or for the installation of two pairs of balanced platform hoists, which could hoist the already loaded ammunition trucks from the magazine level up to the loading platform.

For convenience in handling the projectiles, trolley tracks are shown. These trolley tracks in both the 10-inch and 12-inch emplacements pass from the shell room through the gallery and immediately in front of the hoist wells. In the 12-inch emplacements (Plate XVIII) another trolley track leads from the shot room under the loading platform through this same gallery. In the 10-inch design, however (Plate XIV), the ceilings of the shot room and of the gallery are on different levels and consequently a continuous movement by trolley is not possible, although by using first one and then another trolley track, the shot may be taken by trolley from the shot room to the hoist wells. As an alternative method of handling projectiles in the 12-inch emplacements, in case the ammunition hoist should get out of order, the trolley tracks are extended to the rear doors of the shot room, and cranes are provided in the rear of these doors for lifting the projectiles up to trucks on the loading platform. The last mentioned trolley tracks leading from the rear doors of the shot room to the shell room, can be used also in taking the projectiles into the shell room. These particular trolley tracks are not shown in the 10-inch plans and it is, therefore, necessary in emergency ammunition supply in these emplacements, to roll the projectiles on the floor out through the doors until they come within reach of the cranes.

Plates XIV and XVIII both show on the lower story—in addition to the powder, shell, and shot rooms—guard rooms, a storage battery room, a storeroom for general use, and a relocating room. They each show on top of the battery a small observation station, or crow's nest as it is sometimes called. In the 12-inch emplacements the crow's nest is reached by a stairway from the loading platform and in the 10-inch by a stairway leading directly from the relocating room.

In these designs the powder magazine is given a protection measured horizontally at the level of the ceiling, of not less than 20 feet of concrete and 50 feet of earth, while the parapet protection in front of the gun consists of about 20 feet of concrete and 30 feet of earth.

As a provision for decreasing the amount of condensation, small 6-inch air spaces are shown, passing around the front and sides of the rooms in the traverse and in front of the rooms under the loading platform. Unfortunately, however, these air spaces are shown as blind and have no outlets for drainage; and, as will be noted on the chapter on dryness, it was not unusual for seep water to accumulate in these blind air spaces and to seep through them into the magazines or other rooms, so that though intended to decrease the difficulties due to dampness, these air spaces occasionally made matters worse. However, these designs are an improvement over the 1894 type in providing possible ventilation, the number of doors opening on to the rear face being much increased and these, if left open, permit some circulation of air.

These designs show also a considerable increase in the size and depth of the gun well, but as the size of the gun well is fixed by the Ordnance Department this is an improvement for which the Engineer Department is not entitled to credit.

1898 Type.

Outline drawings of the 1898 type of 10-inch emplacements are shown on Plate XV and of the 1898 type of 12-inch emplacements on Plate XIX.

These designs, like the preceding ones, are of the two-story type, all the rooms on the first story having their floors on the same elevation. The principal improvement over the 1896 type consists in the extension of the truck corridor completely across the rear of the center traverse so as to connect the two loading platforms, thus permitting the personnel to walk from one to another, and also allowing an ammunition truck to be rolled from one loading platform to the gun at the other. It is thus made possible, in case the ammunition hoist of one gun should get out of order, to supply that gun from the ammunition hoist of the other. In view of this possibility and of the improvement in ammunition lifts, it was considered unnecessary to furnish more than a single pair of balanced platform hoists for each gun. The truck corridors of the left guns are shown as covered by splinter-proof concrete roofs, while those of the right gun are open to the sky. Why this was done is not known to the writer.

Another important improvement in this new type is in placing the forward stairway between the two stories in such a position that its lower end is in the magazine space instead of being on the other flank of the gun, as in the 1896 type.

Still another improvement was in providing three crow's nests for the battery instead of one, as in the 1896 type. One of these crow's nests is located on each flank of the battery and one about the center, and they are all placed much farther to the rear than in the 1896 type, so as not to be interfered with as much by the blast effect when the gun is fired. All are reached by ladders instead of by stairways like those in the 1896 drawings, and this makes them slightly less easy to get to.

Another important difference from the 1896 type is the provision of an earth cover in the rear of the magazines. A few years later, however, this earth cover was considered unnecessary and was removed from most of the batteries where it had been placed.

The 1898 type plans of 10-inch emplacements, Plate XV, differ from the corresponding type plans of the 12-inch emplacements, Plate XIX, and from all the other 10-inch and 12-inch type plans shown, Plates XIV, XVI, XVII, XVIII, and XX, in the important particular that the trolley rails from the shell rooms and the galleries through which the trolley rails pass are located in rear of the hoist wells instead of in front of them as in all the other plans. So long as there were installed in emplacements of this type, the balanced platform hoists for the use of which these emplacements were designed, no trouble was experienced from this difference, for it is just as easy, if not a little easier, to pull the loaded ammunition truck backward from the hoist platform to the loading platform, as it is to push it forward as had to be done in the other design of emplacement. However, when the balanced platform hoists had proved to be difficult to keep in adjustment and it appeared desirable to substitute for them the continuous-chain hoists difficulties began to arise, for the chain hoist had to carry up the projectiles and deliver them to a delivery table on the loading-platform level, practically vertically over the receiving table on the magazine level. This required the front-delivery type of chain hoists. When, therefore, it became necessary to install chain hoists in this type of 10-inch emplacements, of which quite a large number were built, and in the similarly arranged 8-inch and 12-inch emplacements, of which a few were built, use had to be made of the somewhat awkward front-delivery type of hoist, of which the lower portion is illustrated in figure 2, Plate I, instead of the much simpler and more satisfactory back-delivery hoist illustrated in figures 3, 4, and 5 of the same Plate I.

Except for the items mentioned and a slightly different arrangement of the rooms on the lower story, the 1896 and 1898 types are essentially alike.

1900 Type.

About 1900, plans of another type of large disappearing emplacement were prepared. Outline drawings of the 10-inch emplacement of this type are shown on Plate XVI.

In these plans there was a considerable rearrangement and an increase in the number of the rooms on the lower story, as will be seen by comparing Plates XV and XVI. This type of emplacement is adapted to the use of the back delivery chain ammunition hoists. The projectiles are carried up by the hoists and are delivered on delivery tables opening through the front walls of the truck corridors. The truck corridor of the left gun is again shown as covered, while those of the other two are open to the sky.

Although not needed for ammunition service, cranes are still shown for emergency use in case the ammunition hoists get completely out of order. For use with the crane or in ammunition supply, trolley rails are shown as running to the rear doors of the shot room. As a possible alternative method of getting projectiles from the lower to the upper story, long ramps are shown on both flanks of the battery. An ammunition truck could in this way be pushed down to the lower story and, in cases of emergency, be loaded there and then pushed to the flanks of the battery and up one of these ramps to the loading platforms of the guns. The shape of the rear of the loading platform level is also somewhat improved by making it a straight line parallel to the line of the gun centers, thus improving the communication between the different loading platforms.

Another improvement is in providing two rear stairways instead of one for getting from the lower story up to the loading platform. Unfortunately, however, these rear stairways are located immediately behind the gun and are, therefore, directly in the way of all movements requiring the mounting or dismounting of the gun or carriage. It was assumed, of course, that the gun and carriage would be mounted once for all but experience has shown that, on account of repairs and alterations, the process has to be repeated not infrequently, and when this is done, stairways in rear of the center of the loading platform have been found somewhat in the way.

The stairway connecting the working platform with the magazine space shown in this plate as circular. It is understood that this was done in order to make less probable the entrance of an enemy's projectile. However, circular stairways are by no means as convenient to go up and down as if they were straight. These plans show ladders for climbing from the loading platform up to the crest of the parapet. Although not shown on the other older plates, it had been customary almost from the very beginning to install such ladders. Stairways instead of ladders are provided for getting to the crow's nest; this is an improvement.

The blind air spaces around the magazines and rooms are shown on this plate as on the plates of the preceding types. The number of doors and windows opening from the rooms on the lower story is much greater on this plan than in the preceding ones, and other openings for ventilation connect the different rooms with one another and with the corridors, galleries, and stairways, so that the ventilation in this new design is much better than in the older ones.

Recesses under the front parapet wall are shown for storing spare ammunition trucks and there are other recesses intended to be used for telephone booths in several different places.

The amount of protection afforded the magazine and guns in this type of emplacement is shown as only about four-fifths of that in the older types.

1903 Type.

About 1903 there were prepared by the Board of Engineers the drawings of a greatly improved type of emplacement. The 10-inch plans were published in the sixth supplement to Mimeograph 36, and are shown in outline on Plate XVII. The 12-inch plans were published in Mimeograph 66, and are shown in outline on Plate XX.

Among the principal improvements in this new type design are: The great increase in size of the loading platforms; the provision of two ammunition hoists per gun; the provision of a special room for the motor generator of the Ordnance Department; the substitution of regular staircases built into the side walls of the loading platforms for the ladders previously used for climbing from the loading platform to the top of the battery; and, most important of all, the greatly improved methods for keeping the magazines and other rooms of the battery dry.

The loading platforms in the 10-inch emplacements are increased in size, to a depth of about 43 feet measured from the axis of the gunwell, and a width of 40 feet on each side of the gunwell to the side wall of the emplacement. The 12-inch emplacements are made about 52 feet deep, measured from the axis of the gunwell to the rear of the loading platform, and 48 feet wide, measured on each side of the gunwell to the side wall of the emplacement. These increases in the size of the loading platforms were made principally because it was expected that longer guns would be mounted in these emplacements and ample space was desired for handling the long sponge and rammer staffs.

Two shell hoists were provided for each gun, not only for the purpose of providing an additional means of raising projectiles should a single hoist get out of order, but also in order to make it possible to change rapidly from one type of projectile to another. Cranes are shown as an alternative method of raising projectiles should the hoists get out of order.

The corridor connecting the two loading platforms is made about 12 feet wide and perfectly straight, and on this corridor there open the hoist wells, the Ordnance Department motor generator rooms, the telephone booths, and the storerooms. Both truck corridors are shown as covered by splinter-proof roofs.

The arrangement of the rooms on the lower floor is somewhat simplified by having fewer rooms and making these larger. Under each loading platform there are three large rooms, surrounded in front, and on the sides by a wide air passage, while at the rear they open on a corridor. In each traverse, likewise, are three large rooms, a shell room, a powder room, and a large and conveniently arranged hoist room. The hoist room has an air passage in front and on one flank, while on the rear and on the other flank it opens on the outer air.

The shell and powder room taken together are built as an inside house in a large magazine space. Between the two is a thick brick wall that serves also to hold up the roof of the magazine space, but the other walls are thin brick walls that do not extend up to the ceiling of the magazine space but only to separate frame and copper roofs. Since these roofs are easy of access they can easily be kept water-tight so that seep water can not get into the shell or powder rooms. The free circulation of air permitted around the thin walls and roof of the powder and shell rooms tends to insure that these walls will practically always have the same temperature as the outside air. Consequently, when this air is permitted to enter these rooms there is no condensation. The effect of the air passage on dryness and condensation will be discussed much more fully in Chapter IX, which is devoted to such subjects.

As an aid to prevention of dampness, the air passages passing around the various rooms, which on the former plans, were shown as blind, are now widened to 2 feet, and are made so as to open on the rear face of the emplacement at several places, and to connect with the various corridors, galleries, and stairways. Incidentally also, numerous ventilators leading from the air spaces on the lower story up to openings on the side and front walls of the loading platforms were shown in the mimeograph, but are omitted from the outline drawings on the plates. There is thus insured, through the air passages, a good circulation of air, the need of which is described Chapter IX.

However, in spite of the greatly improved provisions for inducing a circulation of air, the plans were deficient in not providing sufficient windows, in showing only solid doors, and in not providing gratings that could be locked and thus keep out intruders while still permitting the free circulation of the air. Incidentally, the air passages in a few places had an unnecessary number of sharp bends which always interfere to some extent with the circulation of air.

The front stairways end on the lower floor in passageways close to the doors of the powder rooms, thus making these stairways convenient for serving powder when carried by hand. By using the guard rooms as passageways the lower ends of the front stairways are readily accessible from behind the battery. In the 10-inch plans (Plate XVII), the upper end of these front stairways is on the loading platform; in the 12-inch plan (Plate XX), on the working platform; but the difference is one of convenience and is not important. The rear stairways are made double and the mistake is again made of placing them directly behind the guns.

The observation stations are shown as metal platforms reached by metal staircases projecting out from the rear of the emplacement proper. Three are provided, one at either flank of the battery and one near the center.

The amount of protection afforded to the magazine, measured horizontally at the ceiling, is about 15 feet of concrete and 45 feet of earth. The protection in front of the gun is about 15 feet of concrete and 40 feet of earth. These figures are slightly smaller than in the 1896 and 1898 types, but are slightly larger than in the 1900 type and are stated in the mimeograph as being sufficient to keep out the Navy 12-inch projectile even with its muzzle velocity.

On one of the sheets of the mimeograph an alternative arrangement of the battery with both magazines placed between the guns is shown, but in the magazine space of this alternative plan the mistake was apparently made of placing the powder rooms outside of the shell rooms instead of the reverse, which is the natural and convenient arrangement.

The few defects of the 1903 type mentioned above were to a considerable extent corrected in the first battery built according to these type plans; Battery Parrott, a two-gun, 12-inch disappearing battery completed at Fort Monroe in 1905. In this battery the air spaces were made with fewer angles than is shown in the type design all the rooms were lined and ceiled with porous tiles or porous bricks, and, in place of the double stairway in the center of the rear of each loading platform, two staircases were provided for each loading platform, one on either side.

1908 Type.

After the publication of the mimeograph showing the 1903 type designs, emplacement construction in this country almost ceased, although there were a few 12-inch emplacements of that type constructed.

The Ordnance Department completed its preliminary designs for the 14-inch disappearing carriage about 1907, and the Board of Engineers at once started to design emplacements for that gun and carriage. The designs prepared by the board were very similar to the 1903 designs, but before being published they were much improved and were redrawn in the Office of the Chief of Engineers, so it was not until 1908 that they were issued as Mimeograph 109. Outline drawings of this type design are shown on plate XXII.

However, although outline drawings of this new type accompany these notes, it is believed that it is highly desirable that any officer studying the subject in earnest should obtain access to the mimeograph, both text and drawings, and should carefully examine them. These are the latest mimeograph plans of large gun emplacements issued by the Engineer Department. They are quite complete and go into many details which can not be shown on outline drawings. The details referred to are those of the contour lines, gutters, drains, mosquito-proof sumps, and other matters connected with the drainage system; the air vents, ventilators, grating windows, and doors of the ventilating system; the tile linings of the walls and ceilings; the details of the water-proofing system; the location of the electric lights and lighthoods, and of the ducts and conduits of the electric system; the routing of the speaking tube system; the hydrants, basins, etc., of the water supply and sewerage system; the details of the hoist installation, trolley tracks, shell tables, powder racks, emergency shell and powder recesses of the ammunition service system; the interior waterproofing surface of the Marshall system of waterproofing; the details of the reinforcing bars, steel columns, etc., and the detailed arrangement of the observation slots and observation openings of the battery commander's station and the plotting room.

The drawings of the 1908 type, both in the mimeograph and on the accompanying plate show only the left half of a two-gun battery, the other half of the battery being supposed to be symmetrically arranged. Both magazines are located between the guns.

In its main characteristics this type of emplacement design resembles somewhat closely the 1903 type. It is of the two-story type, the upper story containing the wide loading platforms which are connected by a covered truck corridor, and the lower story, three groups of rooms, one group under each loading platform and the other in the traverse.

The loading platforms are shown much larger than in the 1903 designs, because they are intended for the 14-inch gun which is longer than the 12-inch. These platforms are 62 feet deep, measured in rear of the gun well and 58 feet wide from the gun center to the side wall.

The covered truck corridor is 12 feet wide, measured in the clear, between the rear wall of the traverse and the columns, and, immediately in front of this corridor and opening on it, are the shell hoist rooms, the powder hoist rooms, the truck storage rooms, and the plotting room.

On the lower story there are five rooms under the loading platform, the increase in the number of rooms over the 1903 type being made possible by the increase in the size of the loading platform. As in the 1903 type, these rooms under the loading platform have an air passage in front of them and on their flanks. In addition to this air passage around these rooms, there is another fore and aft passage, extending along the capital of the emplacement from the front air passage to the rear corridor, this separating these five rooms into two groups. On the lower story of the traverse there are, as in the 1903 type, a shell room, a powder room, and a hoist room for each gun, while in the center of the battery small additional rooms are provided for the use of the officers, either as offices or sleeping rooms. Immediately in front of the hoist rooms an air passage runs from one side of the traverse to the other, being connected at its ends with the fore and aft air passages under the edges of the loading platforms, and at the center of the battery with a special short air passage which extends through to the main rear corridor. In front of the powder room and shell room a passageway 5 feet wide extends not only completely across the traverse but, in addition, a short distance farther in either direction to the feet of the stairways which lead up to the working platforms. By using either of the "long storerooms" as a passageway, this front passageway can easily be reached from the main rear corridor.

As additional inducements to a steady circulation of air through the emplacement, the mimeograph drawings show numerous vents passing through the walls near the ceilings from one room to another or from the rooms to the air passages. In addition, several 2-foot ventilators are shown as passing upward from the air passages to the side or front walls of the emplacement or to the top of the battery. Numerous windows are shown in all of the rooms that open on the truck or main corridors and all door and window openings are fitted with gratings as well as with solid doors and windows. Included among the doorways to be fitted with gratings as well as solid doors are the outer doors of the air passages, all the doors of the shell and powder rooms, and the doors of the shell hoist and powder hoist rooms.

The shell room and the powder room of each emplacement are shown as absolutely separate structures, each built in a large magazine space. This carries out still further the ideas first shown in the 1903 plans, in which the powder room and the shell room are shown as semiseparate structures; that is, only one of the walls of each room serves to hold up the roof of the magazine space.

All of the walls of the powder room and the shell room, as well as their ceilings, are shown as lined with tiles or porous brick. In fact, this is likewise true of all the rooms in the battery. The ceiling tiles are to be of special shape, designed for use in Battery Parrott, Fort Monroe, and shown on Sheet IV of Mimeograph 109.

The mimeograph drawings show the emplacement waterproofed according to a system described in the mimeograph text. This system known as the Marshall system, consists principally of an interior water-proof surface, as described in the chapter on dryness, etc. As a further means of preventing or reducing the amount of water entering the concrete through the hair cracks which are so apt to form in an exposed horizontal concrete surface, a system of reinforcing bars inserted a few inches below the surface is shown in the mimeograph drawing as extending throughout the whole roof of the traverse as well as in the pavings of the loading platforms.

The method of storing ammunition in this type of emplacement is quite different from that shown in the older types. The projectiles are to be stored not on the floors of the shell rooms, but on shell tables built of concrete and containing a tile layer to prevent the conduction of heat away from the surface of the table. The lower tier of projectiles is to rest on steel rails built into the table, and these rails are of the same height as those in the receiving table of the hoist. Short removable rails are to be provided across the passageway, so that the projectiles may be rolled directly from the storage table to the receiving table of the hoist, although in case it is desired to do so, the projectiles can be handled by a trolley running on a trolley rail which passes over the center of gravity of the projectiles on the storage table and over the receiving table of the hoist.

When the number of projectiles to be stored in the shell room is more than sufficient to fill one tier, skids are to be placed upon the lower tier of projectiles and a second tier placed on these skids. For the easy service of the projectiles of the second tier, it is proposed to install a removable upper set of rails across the passageway and a removable upper receiving table on the hoist, so that the projectiles of the second tier likewise may be rolled directly to a receiving table. Consequently the use of a trolley is not actually required in the ammunition service of a battery of this type.

For the storage of additional projectiles, if necessary, it is proposed to make use of the long storeroom under the loading platform, and to make this possible, the trolley rails of the shell room have been extended to and through this long storeroom. In connection with the trolley system it should be noted that, in general, it is laid off in a series of loops so that as soon as one trolley has delivered its load it can be moved on again around the loop without interfering with the motion of succeeding trolleys. Where necessary to go from one loop to another, switches and connecting tracks have been installed. In addition, for the purpose of ammunition supply, a trolley rail has been extended from the hoist room to the rear corridor and across that corridor where it projects in the form of a cantilever from the rear face of the battery. It was recommended in the mimeograph text that the "Coburn" trolleys and trolley track be used, they being the most satisfactory type known at the time.

In accordance with the custom of the times the plans show ammunition cranes placed in rear of the truck corridor just over the cantilever extensions of the trolley rails. However, in the batteries constructed on this type the cranes were not installed.

As in the 1903, and in some of the earlier designs, the projectiles when served to the gun are carried up from the shell room by means of a hoist, which delivers them on a delivery table in the truck corridor. The delivery table is fitted with an escapement to permit one projectile at a time to be rolled into the ammunition truck, which is then pushed to the loading platform.

At this point in ammunition service, however, a modification was intended to be introduced and was shown in the mimeograph drawings. At the time these drawings were prepared the Ordnance Department proposed to do the ramming by a mechanical rammer operated on a special loading car, which was to run on rails set in the loading platform in a circular track concentric with the axis of the gun well. These rails were shown on the original mimeograph drawings, but have been omitted from the plate.

This loading car was to be attached to the gun carriage and was to move around the track as the gun carriage was moved in azimuth. It was intended that the projectile truck with the projectile on it should be run up alongside the loading car. The projectiles would then be rolled from the truck to the receiving table of the loading car, and when the gun had fired a shot and had recoiled into its loading position the new projectile would be mechanically rammed from the loading car into the gun. The same rammer was then to ram the powder in in the same manner. However, before any emplacements following these designs were built the Ordnance Department decided not to introduce the loading car or the mechanical rammer. Consequently, the circular loading track was omitted and the loading platforms were finished off smooth as in the former types of emplacements. The old method of serving ammunition by running the loaded projectile truck against the breech of the gun and ramming the projectile in by hand was retained.

The mimeograph drawings show steel powder racks in the powder rooms for the storage of powder, a charge of which was to consist of four cartridges. For raising the powder from the powder room to the truck corridor a special powder hoist was to be installed, and in connection with this powder hoist a powder chute is shown for the return to the magazine of unused powder or of the dummy cartridges used in drill.

One powder hoist and two projectile hoists are provided for each gun, the two projectile hoists being intended to permit a rapid change in the kind of projectile whenever it might be necessary.

For the emergency storage of a few projectiles close to the gun, recesses are shown in the front walls of the loading platform, in which are to be installed emergency shell tables large enough to hold four projectiles each. These emergency shell tables are of the same height as the delivery tables of the hoists and are fitted with similar escapements. Similarly, an emergency powder shelf for storing temporarily a few rounds of powder is shown in the front wall of the truck corridor near the loading platform.

The plotting room is placed immediately in front of the center of the truck corridor and has a door and windows opening on it. Over the center of the truck corridor, and therefore very nearly over the plotting room, is placed a battery commander's station, and between the two, large openings are left so that the battery commander in the battery commander's station can look into the plotting room and see what is going on there and can talk to the personnel at the plotting board. The battery commander's station has a concrete roof and is fitted with observation slots and windows similar to those in use in fire-control stations.

Immediately in rear of the battery commander's station and running the whole width of the traverse is the battery commander's walk at the same height as the floor of the battery commander's station. From any point on this battery commander's walk a clear view of the field of fire can be obtained over the battery, and from either end of the walk a person can look down into one of the loading platforms.

The plans show a power room in the battery, one of the rooms under the loading platform being utilized for that purpose. It is intended that there should be installed in this power room two of the standard 25-kilowatt, gasoline-actuated generating sets, with their radiators. Normally, the fans are to blow the heated air from the radiators to the outside, but in order that it may be possible to warm up the battery in the early spring and thus reduce the amount of condensation later, a hot-air flue is shown as passing from the power room across the entire front of the battery. At various places this flue is connected with the front passageway by branch flues, controlled by dampers, by the proper operation of which warm air can be thrown in at any point of the emplacement. The reason for this expedient will be explained in Chapter IX on dryness, etc.

In the mimeograph drawings, this hot-air flue is shown as circular in cross section and about 4 feet in diameter. In the batteries actually constructed there has been substituted for the hot-air flue a passageway about 2½ feet wide by 6½ feet high, and doors have been substituted for the dampers.

For communication between the lower and upper stories there are the interior stairways connecting the front passageway with the working platforms, and five other stairways in rear of the battery, one in the rear of the center of the battery, and one on each side of each loading platform. The sides of the loading platform are considered better positions for these stairways than the center, as in the former position the stairways will not interfere with or be injured by the process of mounting the gun or carriage. For communication between the loading platform level and the battery commander's walk three stairways are provided, one in the center of the battery behind the plotting room and the others at each flank of the traverse. For reaching the top of the battery, stairways are provided on each side of each loading platform; and for getting from the battery commander's walk to the top of the traverse, a stairway on each side of the battery commander's station. All exterior stairways and the battery commander's walk are shown as built of reinforced concrete, supported by reinforced concrete brackets, projecting as cantilevers from the rear walls or columns of the battery.

The mimeograph drawings likewise show hand rails wherever they are considered necessary, such as on all exterior stairways and along the rear of the loading platform, of the truck corridor, and of the battery commander's walk.

1912 Type of Disappearing Emplacements.

When, in 1908, mimeograph 109 was published, and for several years thereafter, emplacement construction in this country was quite inactive and consequently no emplacements following the 1908 design were actually built, though in the next few years in our tropical possessions, quite a number of 14-inch emplacements and some 12-inch emplacements were built along the general lines of mimeograph 109.

In the meantime, however, the question was being agitated as to whether the general type previously used in designing disappearing emplacements for heavy guns was the most satisfactory. These designs all followed the two-story type, which had the disadvantage of requiring in ammunition service that the ammunition be raised from the lower or magazine level to the upper or loading platform level. However, this type of construction was supposed to possess the great advantage of concealing the exact position of the gun, which was accomplished by placing the crest of the whole battery in a horizontal plane. As long as nothing was allowed to project vertically above this horizontal plane, this important advantage was retained, but for a few years back it had become customary to build battery commander's stations in rear of the batteries, so as to project above the crest line. A battery commander's station of the kind with a splinter-proof concrete roof had been embodied in the 1908 designs and is shown on Plate XXII. This battery commander's station is visible to the enemy, its position with respect to the gun can be noted whenever the gun appears in battery, and thereafter the battery commander's station may be used as an aiming point for projectiles directed not only at the station itself but also those directed at the gun. In this way the principal advantage of the two-story type battery—that is, concealment of the position of the guns, is lost; while the principal disadvantage, the necessity of using mechanical hoists, is retained.

The question was, therefore, discussed as to whether it might not be advisable to change to the one-story type of battery providing horizontal ammunition service. Consequently, when in the summer of 1911 the writer of these notes was detailed as the designing engineer of the Panama fortifications he was directed by the Chief of Engineers to design the heavy emplacements on the one-story, horizontal ammunition service plan.

The detailed designs of the 14-inch batteries were completed in 1912, and consequently this type of design is properly called the "1912 type;" but as it was first worked out in connection with the Panama fortifications, it is ordinarily known as the Panama type of emplacement and is several times referred to by that title in these notes.

Plate XXIII shows the outline drawings of one variety of this type, called the "1912 (M) type" and Plate XXIV, another variety called the "1912 (S) type." A comparison of these two plates will show that these two varieties are exceedingly similar. The first or "M" variety is suited to locations where flank fire is not to be expected and where, therefore, it is safe to have the truck corridor enter the magazine traverse in the most direct way—that is, from the side. The "S" variety is intended for locations where the possibility of flank fire is considered too great to permit an opening into the magazine from the side of the loading platform. This entrance must, therefore, be made from the rear.

The essential principle of both varieties is horizontal ammunition service; each emplacement having a loading platform, a corridor, two shell rooms, and two powder rooms, all on the same level—the floors of all being continuous and, except for slight drainage slopes, at exactly the same elevation.

In this type of battery both of the shell rooms and both of the powder rooms open on the truck corridor, and at the truck corridor end of each of the shell rooms there is placed a service shell table, large enough to hold eight projectiles, and fitted at its service end with an escapement similar to that ordinarily used on the delivery tables of ammunition hoists. When the time comes to serve a projectile to the gun, a truck is run up alongside the escapement end of the shell table, which is just high enough for the purpose, and a projectile is rolled from the shell table to the truck in exactly the same manner as is done in the older type of emplacements from the delivery table to the truck. The projectile is then pushed directly from this shell table to the breech of the gun. The powder is picked up by the powder detachment, at the service end of the powder magazine, and is carried to the gun either by hand or in a hand-barrow. Consequently, in the ammunition service of this battery no mechanical hoists are required.

A trolley track is shown passing in a loop around through both shell rooms and over both shell tables. The trolleys and differential blocks are to be used for raising the projectiles from the floor of the shell rooms where they are normally stored and placing them on the shell tables. Not less than four trolleys are furnished for each gun and, consequently, the work of keeping the shell table filled should be easily done as fast or faster than the projectiles can be carried away by trucks and can be fired by the guns. The trolley track is shown in the form of a loop so that when one trolley has deposited its shell upon the shell table, it can be run on around the loop and not interfere with the motion of succeeding trolleys. In each variety of this type of emplacement an extension of this trolley track is shown as running back to the rear part of the emplacement where it passes over a railroad track on a level sufficiently below that of the truck corridor to permit a loaded railroad car to pass under the trolley rail. Since this railroad track is connected with the main railroad system of the post, the movement of projectiles into the magazine in ammunition supply is made quite simple and easy. In all these new types of emplacements the trolley rails are composed of 7-inch I beams, and the Chisholm-Moore trolleys, differential blocks, tongs, and frogs are used.

The powder magazines were designed upon the idea that the powder charge would be furnished in four cartridges which were to be stored in specially designed steel powder racks. Before, however, these racks were actually built and placed in the batteries the question was raised as to whether it would not be desirable to put up the powder charge in a single cartridge, for which, of course, the racks designed for the four-cartridge charge were unsuited. Consequently these racks were never built.

This type of emplacement has the advantage of horizontal ammunition service but it has the disadvantage that with the floor of the magazine and loading platform on the same level, the head room and cover necessary for the magazine cause the magazine traverse to project high into the air above the parapet in front of the gun. However, in actual construction, the top of this traverse is rounded off in a gentle slope and at the long range from which it is expected it will generally be viewed by the enemy, the battery can not be said to be unduly conspicuous.

In front of the loading platform there is shown the usual variety of parapet consisting of a concrete wall about 20 feet thick with a thick mass of earth in front. In the immediate vicinity of the gun and in the angle bounded by the limiting lines of fire of the gun, the interior crest of the parapet is made horizontal and its top is finished off with the elevations and slopes required by the necessity of clearing the field of fire. However, toward the sides of the loading platform, the crest of the parapet instead of being horizontal as in the old two-story type of battery, rises slightly as it proceeds from the gun thus giving greater protection to the loading platform and, in the "M" variety, to the truck corridor entrance of the magazine.

A very essential difference in this type of battery from the preceding types is the abandonment of the concrete side walls of the emplacement and the substitution for them of sand slopes rising gently from the edge of the loading platform up to the cover over the magazine traverse on one side and up to the top of the flanking traverse on the other.

At both of the locations where the original emplacements of this type were built, fire from the rear was not possible and, consequently, it was not necessary to protect the gun and emplacement from such fire. The rear of the loading platforms is, therefore, left open so that an enemy's projectile will find nothing to stop it in its flight to the rear. In a few other emplacements, however, fire from the rear was not only possible but probable and the construction of a parados was, therefore, essential. This will be discussed a little later.

The two varieties of emplacements shown on the two plates differ mainly, as was stated above, in the location of the truck corridor entrance. In the "M" variety, Plate XXIII, this entrance is at the front of one flank of the loading platform, consequently the truck corridor is perpendicular to the capital of the battery and the shell rooms and powder rooms are parallel to this capital. In the "S" variety, Plate XXIV, the truck corridor enters the traverse from the rear and essentially parallel to the capital of the battery, and the powder magazine and shell rooms are, therefore, essentially perpendicular to the capital of the battery. The arrangement of the other rooms in the traverse must, of course, accord with the arrangement of the powder rooms and shell rooms, and, incidentally, with the topography of the site. Of the rooms and passages in the traverse, the most essential are, of course, the truck corridor, the powder rooms, and the shell rooms, but in addition to these both plates show a plotting room, a power room, a storeroom, a guard room, and a latrine. No air passages are provided for inducing a circulation of air and no tile linings are used because the emplacements built in accordance with the plans shown are located in the Tropics, where the temperature is nearly uniform throughout the year and where, consequently, no trouble is experienced from condensation. However, in order to make the magazines less uncomfortable when a number of men are working in them, it was considered desirable in a number of the Panama batteries to install fans for artificial ventilation. One such is shown on Plate XXIV.

The power rooms in both varieties are each large enough for the installation of two standard gasoline actuated generating sets with their radiators, and in order to prevent the hot air blown out by the radiators from being drawn back into the engine room, the radiator flues are shown ending a considerable distance from the power room. The gasoline tanks are located outside of the emplacement. This was always done when possible, and as an additional precaution the tanks are placed in pits about three or four feet deep. After the tanks are placed in their pits and the pipe connections are made, the pits are filled with sand so that no part of the tank except the filling pipe projects above the ground.

In all 14-inch batteries built in the last few years, even though structurally composed of two emplacements, each emplacement has been fitted so that tactically it may be used as an independent battery. That is, each gun is provided with its own battery commander's station and plotting room. In order that persons in the battery commander's station may obtain a clear view of the field of fire, it is essential that the battery commander's station be placed on top of the traverse; furthermore, to get as far away as possible from the blast of the gun it has to be at the rear of the traverse; and it should be sufficiently to one side to permit a view to be obtained from it of the gun and of a part of the loading platform. This fixes its position within narrow limits. In order that the usual voice-tube communication between the battery commander's station and plotting room may be possible, the plotting room has to be practically under the battery commander's station, and in order that the plotting room may be given the maximum protection, it is necessary to place it on approximately the same level as the powder rooms and shell rooms.

The difference in elevation between the plotting room and the battery commander's station thus rendered necessary is so great in the "M" and "S" varieties that there remains sufficient space for an intermediate story. This is utilized in both these varieties as a place for an officer's room and toilet, the doors and windows of which are shown on the rear elevations and sections, as are the stairways leading from the lower story to the intermediate story and thence to the battery commander's walk and battery commander's station.

The battery commander's station shown has a one-level floor and is an open station, though for the convenience of the personnel in peace time pipes for holding an awning are indicated on the drawing.

The drawings show also the tunnel connecting the plotting room and the mechanical range indicator on the left of the gun. The mechanism of this indicating apparatus is operated from the plotting room; the data is displayed in a niche cut in the upper part of the stairs around the working platform. After the original plans of these batteries were completed, they were modified at the request of Gen. Weaver, then Chief of Coast Artillery, by providing, on the left side of the loading platform of each gun, a time-range board and for the use of the men operating this time-range board, the data displayed by the mechanical range indicator to the detachment at the gun is also shown at another place where it can be seen by the men operating this time-range board.

The drawings show also the passageway and stairway for proceeding from the working platform down into the gun well. It leaves the loading platform in front of the gun and proceeds around and downward and enters the gun well between two of the hold-down bolts. For convenience in getting to the mechanical-indicator apparatus this stairway connects with the mechanical-indicator tunnel.

Another variety of the 1912 or Panama type of emplacement which may be called the "W" variety is shown on Plate XXV. At first sight it would appear that the plans shown on this plate are a return to the two-story type of battery, but a study will show this is not true. The upper story of this variety, considered by itself, is a complete one-story battery, each gun having its loading platform, its truck corridor, its shell room, and its powder room on the same level. Consequently the service of ammunition is horizontal and no hoists are needed in ammunition service.

The battery of two guns shown on this plate is, therefore, really of the one-story type, although it resembles the two-story type. The reason for building it in this way was that the site where this particular battery was to be built was exceedingly low. To build the battery on this level would have required that the bottoms of the gun wells be sunk so far below sea level that they would be difficult and expensive to build and also would, in all probability, subsequently give trouble in keeping water out. In order to reduce this trouble within reasonable limits, it was evidently necessary to raise the battery quite a number of feet into the air and, after a study of the subject, it appeared well to raise it so high as to give room for an additional story under the loading platform level, which in this case is also the magazine level.

This makes it possible to reduce slightly the size of the magazine on the loading platform level, part of the ammunition, only, being kept in this, what may be called "service magazine," the remainder being kept in the "storage magazine," located on the lower story directly under the service magazine. The service magazine contains more ammunition ready for immediate service than will probably ever be used in a single engagement, and it is intended that between engagements the ammunition that has been fired shall be replaced by raising into the service magazine some of the reserve ammunition previously stored in the storage magazine on the lower story. For convenience in raising powder and shell from the lower story to the upper, openings through the ceiling of the storage magazine to the floor of the service magazine are shown. Special mechanical hoists were installed in these openings and, since this is a process for which extreme haste is not necessary, the refinements necessary in the hoists of the two-story type of battery are not needed. Trolley tracks are shown on both stories, those on the lower one being extended to the rear so as to be available for ammunition supply.

The arrangement of the front parapet wall, of the sand slopes on the sides of the loading platform, of the rounded-off top of the center traverse, of the battery commander's walk and battery commander's stations, and of the stairways leading to them are quite similar to those of the "M" and "S" types shown on Plates XXIII and XXIV.

Raising of the battery sufficiently high for an additional story under the loading platform and service magazine level, leaves much spare space on this lower story. Structurally, only the concrete walls necessary for supporting the upper story are required. In some places the voids are, for reasons of protection, shown as filled with sand, but the rest of them were left open and fitted as rooms. They are furnished with doors and windows and, on the detailed plans, are shown as being electrically lighted and are thus available for use. On Plate XXV some of these rooms are shown as being assigned to particular uses—reserve powder rooms, reserve shell rooms, officers' room, plotting rooms, latrine, power room, guard room, storerooms, pump rooms, etc. The other rooms are not marked and are, of course, available for miscellaneous use.

The plotting room is placed on the lower story in order to give it the maximum protection possible. In this case, instead of the indicator tunnel leading from below the floor of the plotting room, it is intended that the wires and shafts of the mechanical indicating apparatus shall pass out just below the ceiling of the plotting room, through openings left in the intervening walls, to the proper place under the loading platform on the left side of the guns.

The power room is shown as occupied by four standard 25 kw. generator sets. Only a part of this power is for use at this battery itself, the remainder being required by neighboring batteries, searchlights, etc., or as a reserve.

In spite of the elevation to which the loading platform in this battery was raised, the bottom of the gun well still remains some 6 or 7 feet below mean tide level. The natural drainage of such wells is, of course, impossible, and in the heavy rainstorms which occur in the tropics considerable water will, of course, find its way into them. It is, therefore, considered necessary to install pumps for removing this water, and pump rooms are shown located on the sides of the passageways leading into the gun wells.

The great width of the loading platform required by the 14-inch gun and the provision of sand slopes on the sides of the loading platforms make it necessary to separate the guns to about 320 feet, center to center. This makes the battery quite long, and it is considered necessary to install six stairways for communication between the lower story and the loading platform level.

The main line of railroad behind the battery was a part of the main post railroad system and was connected with the Panama Railroad. The sidetrack behind the center of the battery passes under the cantilever extension of the trolley rail and was intended for use in ammunition supply.

In the drawings of this battery, and, in fact, also in Plates XXIII and XXIV, so-called "breech recesses" are shown as cut in the front parapet wall, a few feet to the right of each gun. These are required to provide space for opening the breechblocks after the gun has been fired in the farthest possible position to the left.

The main important features of the large Panama emplacements are illustrated on one or more of these three plates, XXIII, XXIV, or XXV, but there are, in addition, a few details of some of the batteries that would appear to deserve mention.

In addition to the battery illustrated as the "W" variety on Plate XXV, there was another battery built in two stories, but for quite a different reason. The "W" battery had a story built under it, as it were, because the site was so low; this was done in the other battery because the site was so high. It was built on a high conical hill, and in order to avoid the cost of cutting the hill down too low, it appeared to be well to keep the battery high by reducing the size of the traverse. This was done, as in the "W" variety, by storing some of the ammunition in service magazines on the loading platform level, and some in storage magazines on a lower level, and by dividing the other essential rooms between these two stories.

In a few of the Panama batteries where the conditions were specially suitable an earth cover was placed over the concrete roof of the traverse in a manner similar to that shown on Plate XXVI. When this was done a different method of waterproofing was used. Instead of using the Marshall system of an interior waterproof layer within the mass of concrete, the waterproofing was done on the upper surface where the waterproof material is protected by the sand covering from exposure to the atmosphere.

The only two-gun battery illustrated is the "W" variety on Plate XXV. In this battery the magazines of both guns are arranged and are entered from the rear as in the "S" variety, Plate XXIV. Some of the other two-gun batteries have their magazines arranged as in the "M" variety, Plate XXIII. The two magazines are between the guns, and the truck corridors of both emplacements enter the traverse from the side, close to the parapet in front, and meet in the center of the battery. The two truck corridors thus provide a continuous passageway from one loading platform to the other.

A few of the Panama emplacements are so located that fire from the rear would appear to be possible, and parados were therefore considered necessary. When built, the parados extends completely around the rear of the loading platform from the outer flank to the magazine traverse, and is made as if it were an extension of the flank traverse in a manner similar to the parados shown for the left emplacement of the battery illustrated on Plate XXVI. On the outer flank the elevation of the top of the parados is the same as that of the flank traverse and the elevation increases as the parados passes in rear of the loading platform until it merges into the top of the magazine traverse. In front the parados slopes down to the rear edge of the loading platform in a slope at least as gentle as the sand slopes on the sides of the loading platform.

In all emplacements where it was necessary to build parados the magazines and the entrances to them are arranged as in the "M" variety (Pl. XXIII); that is, the truck corridor opens from the front of the side of the loading platform. The shell and powder rooms, of course, open on this truck corridor but the other rooms—storeroom, plotting room, officers' room, and latrine—are placed in the rear of the shell and powder rooms and open on a rear gallery which can be reached by a fore and aft gallery connected with the truck corridor. When the emplacement forms part of a battery, the rear gallery is usually made continuous from emplacement to emplacement, passing through the parados. Where this gallery passes in rear of the loading platform an entrance is made to the rear gallery from the loading platform and provides an alternative route of going from the loading platform into the rooms of the traverse. For passage between the plotting room and the battery commander's station, a staircase is built up from the rear gallery near the door of the plotting room to the battery commander's walk not far from the battery commander's station.

The type of 16-inch emplacement built at Panama is similar to the 1912 type of 14-inch emplacements just described except for the necessary increase in dimensions. The main difference is in the passageway down into the gun well. In order to get the large I beams needed for mounting the gun carriage through this passageway it had to be made straight. The entrance is in rear of the loading platform, and thence the floor of the passageway slopes down to the bottom of the gun well.

The standard horizontal protection for the magazines of all these batteries is the equivalent of 35 feet of concrete, which was calculated to be about 25 per cent greater than sufficient to give protection against the largest naval gun afloat at the time the batteries were designed.

Not long after the development of the 1912 type of design for use primarily in the Canal Zone, batteries of the same general design were started in this country. As was to be expected the detailed designs of these batteries show some modifications from the 1912 type designs described above, but the modifications are hardly sufficient to justify considering these new designs as a new type. They are, therefore, considered rather as a new variety of the 1912 type. Plate XXVI shows the outlines of one of these newer batteries and may be called the "L" variety of the 1912 type.

This Plate XXVI shows a two-gun, one-story, horizontal ammunition service battery which, due to the topography of the site, has certain peculiarities special to itself and these peculiarities, therefore, can not be considered as typical. In the first place one gun is emplaced a few feet higher than the other, but the difference is so small that it can be easily overcome in the scarcely perceptible slopes of the connecting corridors and galleries, so that, as far as the movements of persons or trucks are concerned, the loading platforms may be considered as essentially on the same level. Secondly, as will be noted, the right loading platform is open to the rear, while the left has a parados behind it. The parados is necessary in this case not to protect the battery from fire from the rear, but because of the presence of a hill behind the left emplacement. However, the front slope of this parados, the entrance into it, and the gallery through it are quite similar to the same elements of the Panama batteries, where parados were necessary and may, therefore, be considered to illustrate those elements of the Panama batteries.

The most important modifications shown in the battery illustrated on Plate XXVI, which cause it to be considered as a new variety, are the earth blanket over the traverse and the arrangement of the shell and powder rooms.

The concrete roof of the traverse is covered by a blanket of sand from 9 to 12 feet thick and the thickness of the concrete roof has, therefore, been reduced to about 9 feet. This was done occasionally in the Panama batteries, but is now to be considered as an essential element of this later variety of the Panama type of design. The usefulness of the earth blanket has become even more apparent since the Fort Morgan experiments of March, 1916, showed how probable it is that the long-pointed projectiles of the present day will ricochet from a mass of sand without penetrating more than a very few feet.

The addition of the earth blanket over the surface of the concrete has made it possible to insure the water-tightness of this concrete roof at its upper surface and no interior waterproof surface is considered necessary.

The plans of this new variety show also a slight change in the arrangement of the rooms within the magazines. The truck corridors enter the magazine space as they do in the "M" variety (Plate XXIII), that is from the side close up under the parapet; but, after getting well into the magazine space, the corridors change direction and proceed straight to the rear, parallel to the capital of the battery. The shell rooms and the powder rooms are laid out parallel to the line of gun centers, as in the "S" variety, but the shell rooms are in front of the powder rooms, instead of in rear of them as in the "S" variety. After passing to the rear, past the shell rooms first and then past the powder rooms, the truck corridors end in a wide area way which extends from one side of the traverse to the other. In front, where the truck corridors enter the traverse, each is extended a few feet beyond where it changes direction, in a sort of shell trap, to catch and hold comparatively harmless any enemy's projectile that might by any chance be able to find its way into this entrance to the traverse and there explode.

This battery being built at a place where but little trouble has been experienced with condensation, no inside air passages were considered necessary, except the one connecting the truck corridors immediately in front of the forward shell room, which by separating the thin front wall of this shell room from the thick concrete parapet in front should serve to equalize the temperature of this thin wall with that of the air.

The plotting rooms, power rooms, etc., have been located on the front side of the areaway but still within the body of the traverse, while a few of the less important rooms have been placed on the rear side of this areaway in a house which is provided with much less overhead cover.

The battery commander's stations are, as usual, placed on top of the rear of the traverse and on the flanks. They are reached by two stairways, one at each side of the traverse, and are connected by a battery commander's walk. The battery commander's stations shown have their floors on two levels for the reasons which will be described in the chapter on Fire control and the battery commander's walk is placed on the lower level. It is thus too low to provide a view over the traverse, but is connected with the top of the traverse by two stairways running up the sand slope in front of the battery commander's walk.

Criticisms.

Shortly after the Panama batteries were built, they were criticized by a number of officers for their somewhat high cost; for their alleged unnecessary extravagance in the protection furnished the gun, matériel, and personnel; and for the arrangements for the comfort of the detachments. At first these criticisms were made casually, but after they had reached a semiofficial status, the writer of these notes, who had been the designing engineer of the fortifications, thought it necessary to reply to the criticisms and did so in a long letter addressed to the Chief of Engineers. The substance of this letter was subsequently embodied in the annual report of the Chief of Engineers for 1918, from which I quote the following:

> It has been proposed that it would be better and more economical to emplace seacoast guns in a much more simple way than has been the custom; to mount them in barbette, in the open, without protecting parapets; to remove the magazines some distance from the guns and, on account of their decreased liability of being hit, to make corresponding reductions in the thickness of their walls and ceilings; incidently, to minimize the ammunition-handling apparatus within these magazines and to simplify the emplacements generally by doing away with the provisions customarily inserted for the care and comfort of the detachment. It has been argued that such a policy would be in the interests of economy.
>
> The cost of the gun carriage and of the emplacement are but two factors in the total cost connected with the gun, and by no means the largest factors. For every gun that is emplaced there must be the personnel to man it, consisting of officers, noncommissioned officers, and privates, all of whom must be paid, rationed, and maintained. For the maintenance of this personnel, barracks, quarters, hospitals, storehouses, administration buildings, etc., must be built, military posts must be purchased and built and maintained, including their water supply, sewerage, lighting, and other incidentals. Such detachments are required for the gun and for the gun alone, and consequently all items relating to the pay, subsistence, and maintenance of the gun detachment are just as much charges connected with the gun as are the cost of the carriage and emplacement.
>
> Certain of these costs, such as the purchase of sites, the manufacture of the gun and carriage, the construction of emplacements, barracks, quarters, hospitals, and other buildings, and the installation costs of water supply and sewerage, are expenses which are made once for all. Other expenses, such as pay, salaries, subsistence, heat, light, fuel, water, and the maintenance of guns, emplacements, barracks and quarters, roads, etc., are continuing expenses and go on from day to day and year to year. In attempting to make a comparison or summation which include items of first cost as well as those of continuing costs, we must reduce the two to a common basis, either by capitalizing the running expenses or by converting first cost into running expenses by taking into account interest on the original investment and the probable serviceable life of the utility.
>
> Making the comparison by means of the second method, we have for each enlisted man his pay varying with length of service and grade, his subsistence, clothing allowance, his pro rata share of the first cost and upkeep of the barracks, quarters, hospitals, posts, roads, sewers, etc. Calculations made about a year or so ago in connection with Army reorganization bills before Congress, indicated that the annual cost of a private figured in this way, was probably about $900 to $1,000 a year, and that this annual cost mounted rapidly through the various grades of noncommissioned officers and officers until a total of from six to eight times this figure was reached in the case of field officers.
>
> Basing calculations on the 14-inch guns, it is found that the personnel consists of about 70 officers and enlisted men, whose total annual cost amounts to about $90,000. The first cost of a disappearing emplacement for a 14-inch gun was estimated recently at about $200,000 depending, of course, upon location. Assuming 25 years as the utility life of the emplacement, figuring the interest on the original cost at 3 per cent, we will get what might be called the annual running cost at 7 per cent of the first cost. Seven per cent of the first cost is $14,000 and adding to this $3,000, the cost of

annual maintenance, we get as the annual cost pertaining to the emplacement about $17,000, equivalent to the upkeep of 16 or 18 enlisted men, or about one-fourth of the size of the required gun crew. Similar figures make the annual cost pertaining to the gun carriage about equivalent to the upkeep of 7 or 8 enlisted men, or one-ninth of the crew.

In addition to the personnel, emplacement and gun carriage factors, there are many other items of expense, such as the cost of the gun itself, of the power plant, etc.; dividing these costs by the estimated life of each item, adding interest and maintenance and summing up, it is found that the amount is in all something over $130,000 per 14-inch gun per annum. So that the annual charges against a 14-inch emplacement are, for fixed constructions, $17,000; armament, $23,000, and personnel, $90,000. Of these items of annual cost, that relating to the personnel is by far the largest, amounting to fully two-thirds of the whole, while the items relating to the gun carriage and to the elements ordinarily included in the emplacement are respectively only about one-tenth and one-fifth of the personnel cost. Consequently, an increase or decrease of a certain percentage of the cost of the emplacement or carriage will have a much smaller influence on the total cost than a change of the same percentage in the personnel cost.

The cost of a gun carriage for a particular gun depends upon the type, whether it is disappearing or barbette; whether it is all-round fire or limited fire; but it is understood that in the case of large guns, the difference between the cost of carriages of different types does not vary greatly, and as a rule is less than one-fourth of the actual cost of the carriage. Since the annual cost of the carriage itself is shown to be only about 5 or 6 per cent of the total annual cost connected with the gun, a change of one-fourth or one-fifth in this one item would mean a change of but little more than 1 per cent of the whole, and, consequently, any modification in the type of a carriage that would decrease by two men the size of the detachment, necessary for the service of the gun, would pay for itself.

The object of the parapet in front of the gun is to protect the gun and its detachment from the enemy's fire and incidentlly for the psychological purpose of giving the members of the gun detachment a sense of security in action, and thus increasing the rapidity and accuracy of the fire. Whether or not the parapet is needed, that is, whether the detachment should stand behind the parapet or in the open, or whether the gun should disappear behind the parapet or remain always in the open, is still a disputed question, but experiments made some two years ago indicated clearly and conclusively that a parapet in front of a disappearing gun is a real protection to both the gun and personnel and that a fair proportion of projectiles which, in the absence of a parapet, would have struck and detonated in the immediate vicinity of the gun emplacement and would have done serious damage to the gun and personnel, were caught by the parapet and were either deflected or were detonated under such conditions as to do no damage to the gun emplacement or the silhouettes representing the detachment; and that, furthermore, this parapet caught a large number of fragments from projectiles detonated a short distance in front of the gun which, in the absence of the parapet, would have passed among the personnel with considerable probability of causing casualties. Calculations show that the cost of the parapet in front of a gun is less than one-seventh the cost of an emplacement, and the annual cost pertaining to the emplacement does not exceed one-seventh of the total annual cost connected with the gun. Consequently, the part of the annual cost connected with the parapet is but 2 per cent of the whole annual cost, and if this parapet gives sufficient protection to enable a gun to fire 2 per cent more shots at the enemy before the gun is knocked out than would be the case if the parapet were not there, it would appear, neglecting the items of protection given to the men, that the parapet will have paid for itself. That it will do many times more than this is clearly shown by the experiments mentioned. Furthermore, where there are such parapets to give protection, the probable casualties among the gun detachments will probably be much smaller, and the number of additional men which should be kept immediately on hand to replace losses in time of action, would be much less than were there no parapet. The portion of the annual cost pertaining to the parapet is equivalent to no more than the cost of two or three privates. If, therefore, the parapet will permit the number of the reserves available to replace casualties to be reduced by two or three, the parapet will have paid for itself by reduction in the personnel item of cost without considering its effect upon the protection of the gun and carriage.

Wherever placed, magazines and shell rooms must have sufficient protection to prevent their destruction by hostile projectiles, for the result of the explosion of the magazine of a large gun would probably be so disastrous, not only in the destruction of life and property, but in the demoralization of the garrison, that such an occurrence must be prevented, if possible, Such magazines must, therefore, be given thorough protection against aircraft bombs and against direct hits of the enemy's projectiles. If built in plain sight and so close to the gun as to be struck by projectiles aimed at the gun there is the danger, of course, of repeated hits in the same place and slightly greater protection is necessary, but the cost of this additional protection is so small compared with the total cost of protecting the magazine as to make but a small percentage in the total cost.

The further the magazine is from the gun the greater the time necessarily required for the ammunition service and the greater the amount of labor expended, and since the rate of fire against rapidly moving vessels must be as rapid as possible, the farther the magazine is from the gun the larger in general is the size of the detachment which must be kept on hand; and as a result, the size of the personnel item of cost will in general increase much more rapidly than the cost of magazine construction can decrease by permissible reduction in protection. The same is true as to the simplification of ammunition service in the magazine. Any reduction in the installing of appliances for the mechanical handling of projectiles must be accompanied by a corresponding increase in the size of the detachment, and since the total annual cost connected with mechanical appliances for handling ammunition and magazines is probably much less than the annual cost pertaining to a single private, a reduction in the cost of emplacement construction due to the omission of these appliances would seem to be the very reverse of economy.

In time of war, when a hostile fleet is known to be in the vicinity, it may be expected to attack at any time, and the officers and men must remain habitually in the immediate vicinity, and anything that adds to the comfort and mental composure of the detachment or that decreases the time taken for necessary absences, increases the efficiency of the detachment in time of action, and incidentally decreases the number of men whose maintenance is necessary for the service of the gun.

A seacoast gun is designed to combat naval vessels, and can be so used only when the vessels come within range and observation and only as long as the vessels so remain. The destructive power of such guns is known to the enemy, and he will therefore naturally attempt to escape damage by remaining within the fire of the guns for the shortest time possible. This means that the ammunition service of such guns should be designed to be as rapid as possible, and to go to the cost of building guns and carriages, of emplacing them, and of making provision annually for the personnel, and then to attempt to make a saving in any of the small items so as to unfavorably affect the rapidity of service is not only uneconomical but is positively wasteful.

In suggesting greater simplicity of emplacements the critics have, it is believed, entirely overlooked the fact that of the total items of cost connected with seacoast guns, the personnel items are by far the largest, and that the items of the first cost of emplacement construction, etc., though comparatively large, really make up but a very small proportion of the total. Careful study has been given to this matter, and the calculations which have been made clearly and conclusively show that the additional amounts which must be expended in providing rapid ammunition service and in protection of the gun and personnel much more than pay for themselves in the increased rapidity and accuracy of fire, in the increased protection of the gun carriage and personnel, and in a permissible reduction in the strength of the gun detachment. The men whose services are dispensed with are thus made available for use in the field.

16-inch Emplacement Designs.

No 16-inch emplacements based on the designs above described have as yet been built in this country, though many tentative designs for such emplacements have been prepared.

In the year 1914, the question of what modifications should be considered as desirable in the projects for the seacoast defense of about a half dozen different localities in the United States was under consideration, either by formally appointed boards or by groups of officers gathered together by mere informal War Department routine. The reports of such boards or groups of officers were to the general effect that thereafter the 16-inch rifle should be considered as the main primary weapon for seacoast defense and that these guns should be mounted in single-emplacement batteries and usually on disappearing carriages. As these reports were accepted by the War Department and, in the cases of the more formal boards, received formal departmental approval, the recommendations contained in these reports may be considered to have become the policy of the War Department.

The tentative designs for the 16-inch emplacements required by these projects resembled closely the 1912 or Panama type of heavy disappearing gun emplacements, though, of course, the necessary changes in dimensions had to be made to fit the emplacements to the 16-inch instead of the 14-inch guns. The blanket of sand over the traverse pertaining to the "L" variety (illustrated on Plate XXVI) was used in all cases. The arrangements of the magazines and other rooms of the traverse usually followed the "L" variety (Plate XXVI). although the arrangements pertaining to the "M" variety (Plate XXIII) and to the "S" variety (Plate XXIV) were adopted in some cases. Most of these emplacements were to be built in localities where trouble from condensation had been experienced in the older batteries, and consequently special arrangements for preventing, or at least reducing, the amount of condensation were considered necessary—such as semidetached magazine houses and provisions for artificial heating similar to those shown on Plate XXI. The rear faces of the traverses were usually made as concrete walls opening on area ways as shown on Plate XXVI, although in some cases the rear of the traverses had to be given both rear and overhead protection, which required that the rooms in the rear open on a gallery instead of on an open area way. The battery commander's stations were all planned with the two-level floors such as are shown on Plates XXI and XXVI.

The designs just described were used as bases for preparing the estimates of cost to be submitted to Congress, but no actual construction work was ever commenced.

In the meantime war had broken out in Europe and among its early developments were the greatly increased range of heavy artillery and the use of very large guns for firing at land targets. The standard disappearing carriage in customary use in this country restricted the angle of elevation at which the gun might be fired to a maximum of about 20°, and furthermore required the construction in front of the gun and carriage of a parapet which restricted the horizontal angle of fire to an azimuth arc of about 170°. The restriction in elevation reduced the range of the 16-inch gun to far below the ranges then in actual use, not only on land but also in naval engagements. It was was therefore considered important that this state of affairs be corrected promptly, and the Ordnance Department undertook to design a 16-inch disappearing gun carriage which would be capable of all-round fire and would permit firing to an elevation of at least 30°. This would give a range of considerably over 30,000 yards.

To design and build such carriages would, however, require time, and as a provision for the immediate future the Chief of Ordnance suggested that there be mounted on barbette carriages, which could be quickly manufactured, some 12-inch guns which the Ordnance Department had on hand, these guns having been manufactured some years before as spares to replace the emplaced 12-inch guns as the latter wore out.

This suggestion of the Chief of Ordnance was approved by the War Department Board of Review, and the Ordnance Department began at once the manufacture of long-range barbette carriages for these 12-inch guns. These carriages permit the gun to be fired up to an angle of not less than 30° and are capable of all-round fire. The base ring is set in the bottom of a deep gun well. Around the upper part of the gun carriage there is attached a horizontal metal loading platform some 4 feet below the axis of the gun trunnions. This metal platform revolves with the gun carriage and through a slot in it the breech of the gun sinks down as the gun is trained at a high angle of elevation.

1915 Type of 12-inch Barbette Emplacements.

As soon as the Ordnance Department had completed the drawings of the long-range barbette 12-inch gun carriages, the Engineer Department proceeded to design an emplacement for it. The type of emplacement designed for these guns, which in all cases have been mounted in pairs, is shown on Plate XXI.

It will be noted that this emplacement is of the one-story type. The gun well is surrounded by a circular concrete pavement on the same level as and continuous with the metal loading platform of the gun carriage and forming therefore the loading platform of the emplacement. When the gun is to be loaded it has to be turned in elevation until its axis is horizontal, which brings this axis about 4 feet above the loading platform. The ammunition truck is brought up against the breech of the gun and the projectile is rammed into it in exactly the same manner as has been customary in disappearing emplacements. In other words, the ammunition service is similar to that heretofore adopted in disappearing emplacements. After the gun has been loaded it, of course, has to be trained to the proper elevation for firing.

The arrangement of the ammunition space, as shown in Plate XXI and, in fact, of the entire magazine traverse, is similar to that shown for the upper story of the "W" variety of the 1912 type of disappearing emplacement (Plate XXV). Being intended for construction in cold climates where condensation is difficult to prevent, the shell and powder rooms are shown as semidetached houses built in the magazine space. Tile lining for the rooms is indicated and arrangements are shown by which the hot air from the radiator can be blown through the emplacements. The usual trolley tracks for carrying projectiles are shown; also a system of double trolley tracks on the ceilings of the powder rooms for handling the powder charges, which were expected to be furnished in single long cartridges. The rear corridor shown on the plate is to be fitted so that it may be closed in at the rear by metallic shutters sliding on the columns. It is intended that this corridor shall be closed in by these shutters in bad weather, when the battery is manned but is not in action, and thus provide a partially protected dormitory for a part at least of the personnel. The battery commander's station is shown as of the two-level type, which will be described in the chapter on fire control.

The surroundings of the loading platform, however, vary greatly from the former types. The parapet is entirely done away with and the loading platform consists practically of an open and exposed circular concrete pavement, from which a concrete walk leads off to the rear and thence into the truck corridor of the traverse. As has been stated, the axis of the gun is only about 4 feet above the level of the loading platform and if the gun is to be fired horizontally or if the men at the gun are to have a sight on the target it is evident that no parapet is possible. According to the design of such emplacements as shown on Plate XXI, each gun is capable of fire at elevations from zero up to 30° through 275° of traverse; and of fire at an angle of elevation of from 10° to 30°—that is, of the long range fire for which these emplacements were specially designed—for the remaining 85° of traverse. Taking the two guns of the battery together, for 190° of traverse the firing of both guns is possible from zero elevation up to 30°, and for the other 170° of traverse one gun can be fired at zero elevation and up and the other gun from 10° up to 30°.

There are a few cases, however, where the conditions as to depths of water in the vicinity of the site of the emplacement make it unnecessary ever to fire the gun at less elevation than about 10°, and in order to provide concealment and at least the feeling of protection to the personnel of the emplacements built in these localities, it was suggested that a parapet composed of sand without any concrete whatever be built around the loading platform, located far enough away not to be disturbed by the blast of the gun, and built up not quite to the line of the trajectory at the lowest elevation at which the gun might be called upon to fire. Designs embodying this form of parapet were approved by the War Department but, before emplacement construction had reached the state of parapet building, the department changed its mind and the parapets were ordered not to be built. A sketch of a section of such a parapet is shown dotted in Plate XXI.

In one case, as an experiment, it was decided to build the loading platforms of the battery only, omitting the magazines entirely, and to utilize as magazines existing structures quite a distance from the guns. The moving of ammunition from the magazines to the guns was to be performed by motor trucks.

This type of battery construction is surely carrying to a maximum the proposed simplicity of batteries suggested by critics of the Panama batteries. However, as was to be expected, the ammunition service of this battery, after the loading platforms only had been completed, proved to be quite unsatisfactory and requests were subsequently made by the local Artillery authorities for the completion of the magazines between the guns and these have now been about completed.

Later Developments.

While the first long range 12-inch batteries were under construction, the Chief of Engineers received from the Chief of Ordnance a preliminary and advanced copy of the drawings of the new 16-inch disappearing gun carriage which was to be capable of all-round fire up to an elevation of at least 30°. In this type of carriage, all-round fire is made possible by increasing the diameter of the gun well, by making other changes in the gun carriage which place the axis of the gun well not far in front of the center of the length of the gun when it is in the loading position, and by moving the parapet immediately in front of the gun a few feet farther from the center of the gun well than it would naturally be in a limited fire emplacement.

This change, however, does not move the parapet wall as far away from the gun center as is the muzzle, so that the muzzle still projects well over the parapet when fired.

This change in the position of the parapet makes it possible to revolve the gun while in the loading position until it points to what is normally the rear of the emplacement, and in this position, with the breech of the gun toward what is normally the direction of the enemy, the gun may be tripped and fired, and there is ample room for recoil. Of course, the gun can not be loaded in this reversed position, but as this firing to the rear is expected, in general, to be necessary only at land targets, at which fire is usually delivered quite deliberately, the necessity of moving the gun in azimuth before it can be again loaded and of moving it back again when loaded is not considered a very serious objection.

The first emplacements designed for this type of gun carriage were but modifications of the plans previously prepared in 1914 and 1915 and which were briefly described a few paragraphs above. In these new designs, of course, some additional changes had to be made. The emplacement, in the immediate vicinity of the gun well, had, of course, to be suited to the new gun carriage which required, among other things, pushing the parapet in front of the gun a little farther away from the gun well. To enable the gun to be fired toward the flank at zero elevation, the top of the flank traverse and the crest of the parapet on the side toward the flank traverse were both lowered to the elevation of the crest of the parapet in front of the gun. The magazine traverse was retained as of about the same general design as in the 1912 and 1915 plans (Plates XXI, and XXIII to XXVI), because this permitted horizontal ammunition service. Of course, the top of this traverse projected high above the top of the parapet in front of the gun and prohibited horizontal fire over an arc of about 80° of azimuth, but throughout even this limited arc of azimuth, long range fire was still possible at all angles of elevations from about 6° or 7° up. The type of emplacement designed, therefore, permitted horizontal fire through about 280° of azimuth and long range fire through the remaining 80° of azimuth. This it was thought would be sufficient at practically every location where it might be necessary to emplace one of these guns.

However, in order to be prepared, should it be considered necessary that in any location the gun should be so emplaced as to fire as low as zero elevation throughout the whole 360° of traverse, drawings were prepared of still another type of emplacement, and as an aid to a study of this type, a model was made and deposited in the Office of the Chief of Engineers.

If fire is to be possible at zero elevation for the complete 360° of traverse, it is evident that no part of the emplacement can rise quite as high as the trunnions of the gun when in the firing position. The elevation of the trunnions above the loading platform is not sufficient to keep the top of the magazine traverse below the elevation of the trunnions and still permit horizontal ammunition service. Consequently, this change necessitates a return to the two-story type of emplacement, one story consisting of the loading platform level, and the other or lower story of what may be called the magazine level.

In this type of design the loading platform is made practically horizontal and of the size required by the 16-inch gun. In front of the gun and of the sides of the loading platform there is provided the usual type of concrete and sand parapet, the curved part of the parapet in front of the gun and the faces of the parapet in front of the sides of the loading platform, however, being made symmetrical with respect to the center line of the loading platform, which may be called the capital of the battery. The crest of the parapet throughout is made of the same elevation as immediately in front of the gun, and toward each flank this parapet becomes merged into the flank traverses. These flank traverses, one on either side of the gun, run back parallel to the capital of the battery. Their crests are at the same elevation as the crests of the parapet in front of the gun. On the lower story, that is, the magazine level, these flank traverses contain numerous rooms and a corridor, all of which have concrete roofs covered with a blanket of sand. This sa d blanket is rounded off on top, and on the side toward the gun is merged into the sand slope on that side of the loading platform; while on the side away from the gun it merges into the topography of the site.

The corridor of the lower story of each flank traverse extends from front to rear throughout the entire length of the flank traverse, and in front is continued under the whole width of the parapet, so that the corridor is continuous from the rear of one flank traverse around under the parapet and back to the rear of the other flank traverse. In the flank traverses, there are rooms on both sides of this corridor and similarly in the portion of the corridor under the parapet there are rooms both in front and rear of the corridor. The rooms under the parapet are utilized as service magazines both for shell and for powder, while the rooms in the flank traverses are utilized as storage powder magazines for powder not expected to be available for immediate service, as rehandling rooms for powder, as power rooms, plotting rooms, officers' rooms, storerooms, etc.

For raising projectiles from the lower or magazine level up to the loading platform level, hoists or elevators are to be installed, their upper openings being in the parapet wall immediately in front of the loading platform and close to the gun. The exact form of hoist to be used has not been definitely decided. One suggestion considered is the installation of standard projectile hoists, similar to those used in the older two-story type of emplacements. Another is the installation of platform hoists, on which may be raised the loaded ammunition trucks. In one sketch, these platform hoists rise vertically and in another they run up on inclined rails, the upper position being immediately in front of the face of the parapet wall and the lower position, immediately in the rear of the corridor of the lower story.

It has been tentatively decided that the powder service should be by hand up stairways to be provided near the gun, although study had been given to the provision of special powder trucks and hoists.

The plans as drawn show concrete pavements leading from the rear of the loading platform and extending around and into the rear of the flank traverses. These concrete walk ways, however, are not to be made level, but are to have a gentle slope like long ramps, which, leaving the rear of the loading platform at the upper level, would by the time they get well into the corridors of the flank traverse have dropped down to the level of the floors of these corridors. It has been suggested that these long ramps might be convenient for returning the ammunition trucks to the lower story should it be decided that the system of ammunition service shall involve raising the loaded trucks from the magazines to the loaded platform level. Furthermore, the slope of the ramps is not so great but that a loaded ammunition truck can, with the assistance of an additional man or two, be pushed from the magazine level up to the loading platform in case anything should happen to the projectile hoists.

Among the new features embodied in these designs are the provision, in the power room, of air compressors and tanks which, by means of suitable pipes and hose, can furnish compressed air to the gun for use in blowing the gases from the bore in the same manner as is done in the turrets of battleships; and the provision of hot-air flues extending from the radiators in the power rooms to the annular space surrounding the gun well just below the base ring level. In this manner, hot air can, when desired, be blown around under the gun carriage and thus be available for melting snow and ice in wintry weather, so that there will be no danger even in winter time that the gun carriage will freeze up.

During the year 1918 it was urged by several officers who had just returned to this country after service abroad that an elevation of 30°, and the ranges made possible by this elevation, are not sufficient, and that all guns must hereafter be emplaced so as to be capable of firing up to such an elevation as will give the maximum range which is possible with the gun. This necessarily means an abandonment of the disappearing principle and the mounting of the guns in barbette, somewhat in the same manner as is done in the 1915 type of barbette long-range 12-inch carriage.

To accord with this demand, the Ordnance Department has recently prepared tentative designs for a 16-inch barbette gun carriage, capable of firing the gun at practically any elevation. The base ring of this gun carriage is to be set down at the bottom of a gun well as in the 1915 long-range 12-inch barbette gun carriage. Attached to the gun carriage and revolving with it there is an elevated metal loading platform. When the gun is elevated for firing the breech drops down through a slot in this elevated loading platform and when the gun is depressed for loading the breech rises through this slot. It is proposed by the Ordnance Department, in order that the ramming of the projectile into the gun may be easily done, that the gun shall normally be loaded when set at an angle of depression of about 7°. Since the trunnions are only a few feet above the metal loading platform, it is evident that if the gun is to be so emplaced as to be able to fire throughout the 360° of azimuth at zero elevation no part of the emplacement can rise even quite as high as this trunnion level.

Plans of an emplacement in which such guns can be used have been tentatively prepared in the Office of the Chief of Engineers. The gun well is in the center of the emplacement and is surrounded by a loading platform on the same level as the metal loading platform of the gun carriage. This concrete loading platform is not wide and on the outside it is surrounded by an annular V-shaped trench, into which the muzzle of the gun can drop when in the loading position. Outside of this trench the sand rises again to the level of the loading platform. It then continues out very nearly horizontally until it merges with the topography beyond the limits of the emplacement.

The magazines, shell rooms, and other necessary rooms of the emplacement are all on a lower story and surround the gun well. They open on a series of corridors or galleries, the entrances to which from the outside are located in what is generally the rear of the emplacement. The method of ammunition service proposed is to load certain trucks with projectiles and others with powder and to place the loaded trucks on platform hoists which will rise up through trapdoors in the concrete loading platform in much the same manner as is done in raising and lowering merchandise from or to the basements of stores where these basements project out under city sidewalks. . The trapdoors themselves are to automatically open and close, as the hoists come up or go down.

Up to the present time the Ordnance Department drawings of this type of carriage are reported as tentative, and consequently the plans for the emplacement just described must be considered as a study only.

CHAPTER VII.

EMPLACEMENT DETAILS.

In the preceding chapter, the general history of the evolution of the design of heavy-gun emplacements has been brought up to include the latest designs prepared. Attention will now be given to the details of the emplacements, including a few general matters applicable to all emplacements.

Number of Guns in a Battery.

Uniting several emplacements structurally into a single battery has some advantages and some disadvantages.

Among the advantages is reduction of cost. That this is true will be seen at once if we assume that we have the plans already drawn for a number of one-gun emplacements. Each of these emplacements must, of course, be given protection not only in the front but also on both flanks. If now we combine two of them so as to form structurally a single battery, it is evident that in so doing we may omit the flank protection on one side of one emplacement and on the other side of the other emplacement. Consequently, a two-gun battery will generally require less work and will cost less than two single-gun emplacements.

If several emplacements are united into a single battery, the ammunition stored in the magazine of one gun can easily be moved to and be used in another gun if the ammunition of the latter gun should become exhausted or if there should be a breakdown in its ammunition service. Consequently, it is permissible that the reserve stock of ammunition for a battery of several emplacements be somewhat less than the sum of the reserves which should be kept on hand if the emplacements be separated.

Uniting several emplacements into a battery has the additional advantage of making it much easier for one officer to supervise the work of all the emplacements and thus conduces to unity of action.

Another advantage in having several emplacements united into a battery and, incidentally, in having the guns of a battery emplaced close together, is the ease of handling fire-control data. As will be described in the chapter on fire control, the range and azimuth of the target and the other data required for aiming guns are usually calculated for one gun of a battery, which is known as the "directing" gun. Before this data can be used by another gun, corrections must be made and, in general, the closer the guns are together, the smaller the relocating corrections will be and the more easily and more accurately these corrections can be made. Consequently, if several guns are united in a battery, original fire-control data need be obtained for one gun only, the data required for the other gun being obtained by relocating, while if the guns are separated in several batteries the data must, in general, be obtained separately for each battery.

On the other hand, placing guns so close together that they form part of a single battery has a number of disadvantages. In the first place, as will be explained more at length further on, when guns are too close together the blast of one gun, when discharged obliquely toward another, may interfere with the detachment at the next gun or may even drive it away from that gun; whereas, when emplacements are mounted in single-gun batteries, one gun can usually be fired directly over the other battery without seriously interfering with work in that battery.

Another important disadvantage in having guns placed too close together is that one may be struck by an enemy's projectile aimed at the other. Owing to the very long ranges now used, there will probably be a considerable horizontal deviation in the fall of the enemy's projectiles and the greater the distance over which a given number of guns are distributed, whether in one battery or several batteries, the less, in general, will be the chances of having one emplacement hit by projectiles aimed at another.

In addition to the important factors mentioned which should have an influence in determining to what extent emplacements should be grouped into batteries, there is another element which, though theoretically of secondary importance as far as the efficiency of the action of the battery is concerned, is yet quite important in other ways. This element is the question of quartering and messing the personnel pertaining to a battery.

For each gun there must be a detachment of a certain strength, some men to maneuver and aim the gun, some to handle the ammunition in the magazines, some to serve the ammunition, and some to load it in the gun; others are required for fire-control work and for other purposes. In general, the strength of the detachment will depend upon the size of the gun, the method in which it is mounted, and upon the ease of ammunition service. In order that team work may be obtained, it is evidently desirable that the men should be trained to work together and that, in general, the same men should be kept together. In other words, there should be a particular unit of men assigned to each particular gun and to each particular battery.

In peace times it is customary for the men to be quartered and messed in regular barracks at considerable distances from the guns. In order that they may be well acquainted with each other and with their officers and noncommissioned officers, and that the noncommissioned officers and officers may know the men, it is very desirable that the organization for handling the guns should be the same as the organization for quartering and messing; in other words, that the personnel of a battery should be quartered and messed together and under the control of the same officers who are to control the battery in action.

At first sight it would appear that the simple solution of this problem is to have the size of the barracks adjusted to the size of the personnel pertaining to a particular battery, but experience has shown that it is convenient to organize the personnel of an artillery post for quartering and messing into companies of approximately the same size, the company being a command appropriate to the rank of captain, as is normally the command of a single battery. Consequently, it would seem that convenience as well as efficiency will be best obtained, if the emplacements are so combined into the batteries that the number of men necessary for one batttery will be approximately equal to that necessary for other batteries, and will, at the same time, form a company of convenient size for quartering and messing.

Apparently, in the early days of modern-emplacement construction the question of the number of guns which could best be united in a battery was not given very careful consideration, for in examining our older batteries we notice so many apparently inexplicable inconsistencies. Thus it was not infrequent to mount 5-inch guns in single-gun emplacements considerably scattered, while the emplacements of large guns were at times united with as many as three in a battery; again, at one post, immediately next to a battery of two 6-inch barbette guns, there is a battery of three 12-inch disappearing guns.

In general, in the early days it was customary to group 3-inch and smaller emplacements four in a battery, and all larger guns two in a battery or in some cases in multiples of two. However, where large guns were united structurally in batteries in multiples of two, it was probably with the expectation that these structural batteries would be subdivided into tactical batteries of two guns each.

In recent times the advantages and disadvantages of having guns united into batteries have received more careful consideration and, judging from the action of the War Department in the last few years, it would appear that the adopted policy is about as follows: That 3-inch guns should be grouped either two or four in a battery;

that 6-inch guns should be mounted two in a battery; that 12-inch barbette guns should likewise be mounted two in a battery; but that 12-inch disappearing guns and all larger guns should be mounted in single-emplacement batteries, and when, for any special reasons, two such large emplacements are structurally united, they should tactically be manned and operated as if they were single-emplacement batteries.

Relative Position of Gun and of Magazine.

An examination of the plans prepared by the Board of Engineers for disappearing batteries (Plates XIV to XX, inclusive) shows that in all cases the magazines are placed on the left of the loading platforms. Unfortunately, this fact has been taken by some officers to mean that this is the only normal and proper location. This, however, is not true, for there is nothing in the construction of the gun or carriage or in the system of ammunition service to make it preferable to place the magazine on any particular side of the gun. In fact, the arrangement of gun and magazine shown on the drawing probably originated in this way. The original drawings of the Board of Engineers happened to be made with the magazines on the left sides of the guns, and this was continued in subsequent drawings because it was easier for the draftsmen to stick as closely as possible to the old ones. That it was not the intention of the Board of Engineers to imply that the left side of the gun is the normal side for the magazine is further shown by the fact that a number of the early mimeographs which originated with the Board of Engineers, in addition to the main arrangement of guns and magazines for which the details are worked out, show other and alternative outline arrangements and in many of these the magazines are shown on the right of the guns. Furthermore, in the Board of Engineers' plans the left emplacement is usually shown as designed as if it were for the flank gun of a battery of a number of guns, the 170° of possible arc of traverse being generally so distributed as to show 20° of fire in rear of the line of gun centers prolonged and 60° of arc of fire to the right of the capital of the emplacement. On the other hand, the right emplacement is drawn as if it were a center emplacement, its arc of fire being limited to 140° of azimuth, 70 on either side of the capital, since 70° is considered as about the maximum permissible departure from the capital which will not interfere too seriously with the men in the next emplacement.

The greater part of our seacoast batteries have been built on one side or the other of an entrance to a harbor. The enemy is to be presumed to approach from the sea and, consequently, for each particular battery there is one special side from which the enemy may be expected to come. This side, for convenience, we may call the exposed side. The question may now well be asked as to whether it is advisable that the magazine should be placed on the exposed side or on the unexposed side of the gun.

In answer to this question it may be said that in the form of emplacement based on the horizontal crest idea it really makes very little difference whether the magazine is on the exposed or on the unexposed side of an emplacement. If the magazine be placed on the side of the gun toward the enemy, the members of the detachment serving ammunition from the ammunition hoists to the gun will be a little less exposed than if they were on the opposite side; but, on the other hand, the projectile truck and the powder will have to be carried farther to reach the breech of the gun if they come from the side toward the enemy than if they come from the opposite side. Consequently, the relative advantages and disadvantages of these two positions about balance.

However, in the one-story type of emplacement, in which the magazine is placed in a traverse reaching high above the parapet, the loading platform is much better protected from an approaching enemy if the magazine be on the exposed side. Furthermore, if the magazine be on this side, it is permissible to have its main entrance in the most convenient place, that is, on the side of the emplacement as in the "M" variety of the 1912 type (Plate XXIII), rather than in the rear, as in the "S" variety. (Plate XXIV.)

Where there are two guns and but two guns in a battery, there is a considerable advantage in placing the magazines of both guns between them, because this separates the guns farther and not only reduces the blast effect of one gun in the other emplacement, but also makes one gun less likely to be hit by a projectile aimed at the other.

Distance Between Consecutive Guns.

In the seacoast fortifications built before and during the Civil War the guns were mainly smoothbores, and in order to overcome the inherent inaccuracy of the fire of such guns and still bring an effective fire to bear, a large number of such guns were necessary. This required that the guns be mounted quite close together, although in order to reduce the damage that might be done by enfilade, it was necessary to place traverses at intervals along the line of guns. This close grouping of guns was continued in the design of our seacoast defenses long after the necessity for it had passed, and even after the introduction of rifling and other means of improving the accuracy of fire had made it possible to make use of fewer guns and to fire them with greater individual care.

The tendency to the close grouping of guns was shown in almost all of our batteries designed prior to the Spanish War. Thus the early designs for the 3-inch emplacements showed the guns as mounted only 29 feet apart. (Plate III.) Similarly, the oldest designs for the 5-inch emplacements (Plate VI) showed the guns but 45 feet apart, and the first mimeograph of the 6-inch barbette emplacement showed those guns as only 20 feet apart center to center (Plate VIII), it being necessary in order to obtain this close grouping to adopt the inconvenient arrangement of placing both guns between the two magazines.

However, it was not very long after emplacements based upon these early designs were built before it was discovered that if a gun were fired at only a slight angle from the line of gun centers, the blast effect was so great as to interfere with the detachment at the next gun.

About 1904 and 1905 a series of tests were made at Fort Monroe and elsewhere, under direction of a board, to determine the minimum distance which should be allowed between gun centers for different sizes of guns and for different angles of fire. The report of this board is published in mimeograph No. 89, and indicates it to be desirable that thereafter guns should be emplaced farther apart than they had been shown in the early designs, and also that where it could be done without sacrificing other valuable considerations the traverses between guns could well be rounded up to above the level of the guns in the firing positions.

To reduce the blast effect and to make it less probable that one gun will be hit by a projectile aimed at the other, as well as for other reasons, there has been in recent years a steady tendency to spread guns farther apart. Thus the most recent 6-inch guns have been emplaced 170 feet center to center (see Plate XII), as against 20 feet for the battery shown on Plate VIII, while the heavy gun batteries have grown in width from the 124 feet, gun center to gun center, shown for the 10-inch emplacements on Plates XIII to XVI, up to 275 feet for the two-story 14-inch emplacement shown on Plate XXII, and 320 feet for the Panama 14-inch batteries shown on Plate XXV. In several recent fortification projects single heavy gun emplacements have been placed about 300 yards apart, gun to gun.

However, in attempting to obtain the advantages that follow a wide spacing of the guns, the matter should not be overdone, for an unnecessarily wide spacing of guns in a battery needlessly increases the cost of the battery. Consequently, to separate the guns of a battery any farther apart than is necessary to provide conveniently large loading platforms and sufficiently protected magazines, is wasteful.

GUN BLOCK.

The gun block is the portion of the emplacement which supports the gun carriage and the gun. Its size and mass must, therefore, be such as to make it safe from overturning by the shock of discharge. The size and shape of the gun block must, of course, be such as to fit the carriage and consequently, it must be largely designed to accord with the Ordnance Department drawings of the carriage. In fact, except for a few details such as drainage, bringing in electric cables, etc., the Engineer Department, in preparing gun-block designs, has but little freedom or responsibility.

In small and medium caliber barbette emplacements, the gun block is usually quite simple in design, its upper surface being nearly flat and merging off into the loading platform (see Plates III to IX). In the older masking emplacements the gun block was likewise quite simple, although it contained the gun well in which the counterweight was raised and lowered.

In the larger disappearing gun emplacements, however (Plates XIV to XX and XXII to XXVI), the gun block is quite large and complex. It is usually separated from other portions of emplacements by "planes," or more "properly, surfaces of weakness."

In the center of the gun block is the gun well, cylindrical in shape. (See Plate XXIII.) The upper edge of the cylindrical wall of the gun well lies in a horizontal surface, called the "base ring level." The base ring level is usually from 4 to 10 feet wide and is surrounded by a vertical cylindrical wall from 2 to 4 feet high, the axis of the cylinder being coincident with the axis of the gun well. The upper edge of this cylindrical wall, in turn, lies in a horizontal surface, called the working platform level. In front this working platform level usually extends outward to the parapet wall, while on the rear and at the side it ends at the foot of a flight of from four to eight circular steps that leads upward from the working platform level to the loading platform level.

The gun block is usually separated from the parapet by a cylindrical surface of weakness, coincident with the inner surface of the parapet wall. (Consult mimeograph 109.) The gun block is likewise separated from the loading platform by another cylindrical surface of weakness. This latter surface of weakness is sometimes coincident with the riser of the uppermost of the circular steps connecting the working and loading platforms, and sometimes it is a few feet farther away from the axis of the gun well, so that structurally a portion of the loading platform forms in reality the upper surface of the gun block. This cylindrical surface of weakness, however, must not be pushed so far from the gun as to lie behind the breach for, if that be done, and if any inequality of settlement between the gun block and the mass under the loading platform occurs, there will be a slight break in the surface over which the loaded ammunition truck must be rolled in ammunition service.

Where there is an annular air space surrounding the gun block, as in the designs shown in mimeograph 109, Plate XXII, it is usual to make the surface of weakness pass through the center of this air space so that any leakage will find its way into the air space, whence it can easily be drained away. (See vertical section on left edge of sheet 2, mimeograph 109.)

In many respects the most convenient location for the surface of weakness between the gun block and loading platform mass is at the riser of the upper step, as was suggested above. In case it is placed there, the loading platform is usually given a continuous drainage slope away from the top of this riser. Where the surface of weakness is placed slightly farther outward, it is usual to make the intersection of the surface of weakness with the loading platform the crest of the latter, the portion of the loading platform within this surface of weakness draining toward the steps and the portion outside to the rear.

Working Platform.

The concrete part of the working platform level should be at exactly the same elevation as the metal part of the working platform attached to and rotating with the gun carriage. The working platform is, of course, completed before the base ring is set, consequently in setting the base ring, care must be taken so that not only is it made perfectly level, but also that it is set at such an elevation as to place the concrete and metal parts of the working platform at exactly the same elevation so that they form practically a continuous horizontal plane.

Although it was not done in the early days, it has been customary for the past few years to provide a metallic curb at the interior edge of the concrete working platform. (See sheet 7, mimeograph 109.) This curb is made of a standard angle iron with a horizontal face of from 3 to 4 inches and a vertical face from 4 to 6 inches. This curb must be bent until it is exactly circular in shape, and this bending must be so accurately done as not to permit a variation anywhere of more than one-eighth of an inch from the proper horizontal distance from the vertical axis which is used as a standard in setting the hold-down bolts. This degree of accuracy is necessary because the metal-working platform whose exterior edge is circular revolves just inside of this curb.

It is usual in large emplacements to make this curb of several pieces of angle iron jointed together, using as fish plates pieces of smaller angle iron. These small angle irons can, of course, be placed on the outside of the curb only.

The anchor bolts holding the curb in position are usually composed of one-fourth-inch or three-eighths-inch rods, countersunk where their heads appear on the cylindrical surface. To hold the bolts firmly in place as the concrete is placed around them, nuts are passed over the bolts and are screwed tight against the outside vertical face of the angle iron. After passing a few inches horizontally, these bolts bend diagonally downward and, near their outer ends, the last 2 or 3 inches is again bent sharply downward almost vertically. Of course, after these bends are made in the anchor bolts it is impossible to get the nuts on them, so that it is customary to insert the anchor bolts in the angle iron and to then screw up the nuts so as to hold them firmly in position before doing the bending.

The heads of the bolts holding the fishplates must likewise be countersunk.

The curb must be very accurately set in position before the concrete is placed around it. The horizontal face of the angle must be absolutely level and at exactly the proper height, and no part of the vertical face must vary by more than an eighth of an inch from the proper distance from the axis of the gun well and of the cylinder passing through the bolts that are to hold down the base ring of the gun carriage

In order to provide drainage for the concrete part of the working platform and prevent water from running over the curb, it is customary to give this part a slight slope outward to a small shallow gutter placed on the working platform level against the riser of the bottom step. This gutter must be provided with drain pipes, preferably leading outward and downward to the air passage where there is one.

Base Ring Level and Hold-Down Bolts.

Upon the gun block rests what is called the "base ring" of the gun carriage, which supports the weights of the gun and carriage and transmits these weights and the shock of discharge to the gun block. In large gun carriages the base ring is composed of heavy pieces of cast iron, usually made in sections and bolted together so as to form, as far as is practicable, a single ring. Its upper surface is planed into a smooth conical path, upon which there move the rollers. The rollers are conical and the point of intersection of the axes of these cones lies in a vertical line passing through the center of the base ring, so that as these rollers move around they roll without sliding. On top of the rollers there is what is known as the racer, which rolls around on them and which supports the remainder of the gun carriage.

In smaller barbette guns the base ring is merely a flange at the base of the pedestal.

The base ring is held tight to the gun block by a number of hold-down or anchor bolts furnished by the Engineer Department and installed by that department during the construction of the gun block. The number of hold-down bolts necessary, their size and distribution, are fixed by the Ordnance Department, and are shown upon Ordnance Department drawings which are furnished to tne Engineer Department. The constructing engineer must see that the location of these bolts and their size accurately agree with the requirements of these Ordnance Department drawings.

Of course, in order that the bolts may be accurately set a templet has to be made. This, under the circumstances, is not a difficult thing to do, though great accuracy is required. Ordinarily the templet is made of wood. The hold-down bolts are pushed through the templet 'and are bolted in place. The templet is then carefully fixed in position so that the bolts are exactly in their proper places and the concrete is set around the bolts.

In a few of the early emplacements constructed it was found, when the attempt was made to set the base ring, that it did not accurately fit the bolts. To avoid this, some constructing officers, when the base ring happened to arrive before the gun block was built, made use of the base ring as a templet. However, the base ring of a large gun is so heavy and unwieldy that this is not believed to be good practice.

In order to allow a little play for the bolts, a few constructing officers have been in the habit, when the concrete had been brought up so as to cover about the lower half of the bolts, of placing over the upper half of each bolt a piece of pipe a little larger than the bolt. The concrete is then placed around the pipe and the pipe is afterwards pulled out, leaving a little play, so that the bolt may be bent a fraction of an inch or so in any direction. Later this space is filled with grout.

This, however, is not believed to be a good practice. The bolt holes bored in the base ring allow a little play for the bolts, and the accuracy obtained in setting the bolts should be such that this amount of play is sufficient.

Unfortunately, when the base rings for one of the long-range 12-inch carriages was, in the autumn of 1918, sent to the emplacement designed for it, it was discovered that one of the bolt holes in the base ring had been bored 2 inches out of place. To have mounted this base ring in this emplacement would have required either that a new bolt hole be bored or that one of the hold-down bolts be cut out and be reanchored in the concrete. Fortunately, however, it was not necessary to do either of these things, because an emplacement for a similar carriage in another place had not been started and the base ring which had been improperly bored was sent to this new place, and the bolts in that emplacement were set so as to fit this particular base ring.

The hold-down bolts have at their upper ends hold-down nuts to press the base ring firmly against the gun block, and above these hold-down nuts lock nuts are added to prevent the hold-down nuts from shaking loose from the repeated shock of discharge when the gun is fired.

At the lower end of the hold-down bolt there is an anchor plate with, of course, a nut below it to keep the bolt from pulling through the anchor plate. Incidentally, unless there is a nut above the anchor plate also, there is a possibility that in placing concrete around the anchor plate some small lumps of concrete may get between the plate and the nut below it. When the base ring is set later the strain put upon the nuts at the top of the bolt may not be sufficient to break up the concrete lump and raise the bolt up so that the bottom nut comes firmly in contact with the anchor plate. These small concrete lumps may subsequently be broken by the shock of firing the gun, and this would leave a little play, which may cause trouble later when the gun is again discharged. To avoid this trouble the anchor plate should be held firmly between two nuts, which should be screwed up hard before the concrete is set around the bolt.

As a general rule the anchor plates are about 12 inches square and about an inch thick, although other dimensions are shown on some of the drawings.

In small guns, instead of having the anchor bolts held down by individual anchor plates, an anchor ring is sometimes provided through which all the bolts pass.

As was stated above, the hold-down bolts are furnished by the Engineer Department, and one of the earlier mimeographs (mimeograph No. 10, issued in 1896) gave specifications for the manufacture of these bolts. These specifications were subsequently amended and were published as a supplement to mimeograph No. 10 and are as follows:

ANCHOR BOLTS AND NUTS FOR 12-INCH MORTARS AND 8, 10, AND 12 INCH GUN

Anchor bolts are to be of soft open-hearth structural steel.

Each finished bolt must be stamped with the melt number, and one extra bolt for test purposes must be supplied with the lot made from any particular melt; said bolt to be selected at random by the agent of the United States.

Tensile strength, limit of elasticity, and ductibility shall be determined by test pieces cut from a selected bolt.

The bending test shall be made upon a test piece cut from a selected bolt and machined to 1 inch square in cross section.

The material shall fulfill the following tests:

Ultimate tensile strength, from 56,000 to 62,000 pounds per square inch; elastic limit, not less than one-half the ultimate strength; minimum elongation, 25 per cent in 8 inches; minimum reduction of area at fracture, 50 per cent; shall bend 180° flat on itself without fracture on outside of bent portion.

The finished bolts must be free from injurious seams, flaws, cracks, and have a workmanship finish.

Anchor plates to be of a tough gray cast iron, free from injurious cold shuts or blow holes, cored and beveled as shown on the platform sheets; the holes in the anchor plates to be roughly finished to fit the bolts; the surface under the head of the bolt affording a through bearing.

Bottom nuts of anchor bolts to be square and one-half inch thicker than United States standard, of best quality of wrought iron, hot pressed, and of same quality and finish as bottom nuts, conforming to the United States standard in size, except thickness, of jam nuts.

The hold-down bolts, of course, have to be inserted in the concrete when the gun block is constructed. In order to preserve the thread at the top of the bolt it is customary to leave the nuts on throughout the process of building the gun block and, in order to preserve the nuts and the upper ends of the bolts from the concrete and moisture, it is customary to tie them up with oiled rags which can afterwards be removed. These rags are, of course, allowed to remain on the bolts until the base ring arrives.

The first step in mounting the gun carriage is to set the base ring. The rags and nuts are removed from the top of the bolts and the ends of the bolts are carefully cleaned and oiled. The base ring is then carefully manipulated over them and slowly lowered with jacks until it is set in place.

It is essential, of course, that the roller path of a large gun be absolutely horizontal, and great care must, therefore, be exercised in setting a base ring to see that it is carefully leveled. In order to insure this, each base ring is provided with a few so-called leveling bolts. These screw through the base ring and press against leveling or thrust plates furnished by the Ordnance Department and for which recesses must be left when the concrete is finished off near the heads of the hold-down bolts. (See sheet 7, mimeograph 109.)

After the base ring has been lowered over the hold-down bolts, these leveling bolts are carefully adjusted so as to make the base ring absolutely level and at the proper elevation. There should be left under the base ring and between it and the concrete surface of the gun block a space of from one-half an inch to 1 inch. This space is then to be filled with grout.

As was stated before, in setting the base ring of a large gun there is one matter of special importance and that is that it should be set at exactly the proper height so as to bring the level metal platform, known as the working platform, which revolves as the gun revolves, exactly in the same horizontal plane with the concrete part of the working platform level. The curb of the working platform level should, therefore, be taken as the basis on which all other levels around the gun block are based, and when the base ring is set its exact elevation and the amount of grout which is to be placed under it should be so adjusted as to bring the metal part of the working platform to exactly the proper elevation.

The grout used in setting the base ring consists of a very thick and dry cement paste composed of neat cement and water. This is forced under the base ring until the entire space is filled and filled solidly. The cement is then given a few days in which to harden, leveling bolts are loosened, and the hold-down bolts carefully tightened up. An examination is then made to see if the base ring is still level; and if so, the mounting of the other parts of the carriage may be proceeded with.

The Chief of Ordnance has stated that in setting the base ring for a large seacoast gun a variation of one-fiftieth of an inch is not permissible. Specially designed machinist's levels are therefore required, and in order that the blame for any error may fall on the proper department it is customary for a base ring never to be set except in the presence of and under the supervision of an Ordnance officer or an Ordnance Department mechanic.

The actual grouting of the space under the base ring is done by the Engineer Department.

At new posts, where emplacements are under construction and there is no Artillery garrison, the handling of the base ring and the mounting of the carriage is done by the Engineer Department, that is, by Engineer Department civilian employees working under the supervision of an Engineer officer. At garrisoned posts where artillery is available, the Artillery soldiers mount the gun and carriage, the Engineer Department giving such assistance as may be necessary and always grouting the base ring. Wherever large guns and carriages are to be mounted or remounted, the Ordnance Department should, in general, be represented by an Ordnance officer or by a designated civilian Ordnance employee.

As a rule the Ordnance Department drawings make no allowance for the grout under the base ring and constructing officers should, therefore, be careful to finish the surface upon which the base ring is to rest half an inch or so lower than the Ordnance Department drawings would indicate and should then see that the base ring is set not only absolutely level but at exactly the proper elevation.

Care should also be taken, in finishing the upper surface of the concrete of the base ring level, to leave recesses for the leveling plates. Space also should be left for the joints of the base ring where, as in very large guns, it is furnished in more than one piece. In addition, a groove, annular in shape, should be left for the elevating mechanism to revolve in. The bottom of this groove should be so arranged as to drain to pipes set at a few low points. In high emplacements these drain pipes should lead outward to the gutter in the air passage; in low emplacements, inward to the gun well.

On the inner face of the gun block, or it might be better to say in the wall of the gun well, recesses should be left for the Ordnance Department terminal box. (See sheet 7, mimeograph 109.) Grooves for speaking tubes, electric cables, and flexible connections should likewise be left.

Gun Well.

The main purpose of the gun well is to provide space in which the counterweight may rise and fall. In the old masking mounts the counterweight exactly balanced the gun and pedestal. It dropped down when the gun rose to the firing position and was raised when the gun dropped down to the concealed position. These wells, of course, were not very large. (See Pls. III and VI.)

With the disappearing carriages the counterweight fulfills two functions: First, the work done in raising the counterweight as the gun recoils serves to absorb some of the energy of recoil; and, second, when the counterweight is allowed to descend it raises the gun into the firing position.

In the oldest form of disappearing emplacements (1894 type, see Plate XIII) the counterweight wells were made so small that the counterweight nearly filled the well, and it was found extremely difficult to put the counterweight in position as the gun was being mounted. In order to improve on this, an opening from the flank was cut into the bottom of the gun well, through which opening a man could crawl and through which he could pull out any cribbing which had temporarily been placed under the counterweight. Similar openings were installed in some of the earlier masking emplacements. (See Plate VI.)

The next improvement was to make the gun well very much larger so that the counterweight fills up but a very small proportion of the space within the well. This permits communication wires, electric-light wires, speaking tubes, etc., to be carried into the well and through it to the gun carriage.

Until the development of the Panama type of emplacement, the only method of getting into the gun well after the gun and carriage had been mounted was by means of a ladder hung downward from the upper part of the gun carriage to near the bottom of the well. This, however, was found to be inconvenient, and in the Panama type of battery a special passageway is provided leading down into the gun well. This makes it easy for a person at any time to go from the loading platform into the well. (See Plates XXIII, XXIV, and XXV.) Such a passageway was especially necessary in the Panama 16-inch disappearing emplacements, where long and heavy steel I beams had to be carried into the gun well for use in mounting the gun and carriage.

Of course, the rain that falls upon the gun or carriage drains into the gun well. Some form of drainage is therefore essential. When the gun well was small the amount of water which would accumulate in it was also small, but as the gun well and the space around the loading platform which drains into it increased, the amount of water which might accumulate also increased and a corresponding allowance had to be made for this increased drainage. To catch the drainage, a sump is placed in the floor of the gun well and the floor is drained toward this sump. Sometimes the sump is placed centrally, but more often at one side.

In general, as will be discussed in the chapter on drainage, all portions of an emplacement should be provided with natural drainage, and when the emplacement is located on a high site it is usually possible to provide such drainage even for the gun-well sump. However, the gun wells necessary for the standard large disappearing emplacements are so very deep that when these emplacements are constructed along the low sand beaches of the South Atlantic and Gulf coasts the floors of the gun wells are pushed down well below mean sea level, and therefore below the level of ground water. Natural drainage for such low wells can not be provided. Of course, with proper construction, no seep water should find its way into these wells, but rain water does, and the only way of removing it is by bailing or pumping. Consequently, in one of the Panama batteries where the bottom of the gun well is several feet below sea level, special pump rooms had to be provided on the sides of the corridors leading into the gun wells. In these pump rooms small hand pumps were installed. In general, the amount of water which can accumulate in such a gun well should be very small, and it was thought that power pumps were not necessary and that hand pumps would suffice. (See Plate XXV.)

LOADING PLATFORMS.

The loading platform is the name given to the level space surrounding the gun and carriage upon which the members of the detachment stand while placing the ammunition in the gun. In small emplacements the loading platform is not large (see Plates III to VII) and from its rear there is usually a flight of steps leading down to the magazine.

In the medium caliber, rapid-fire, barbette emplacements the loading platform is slightly larger. Occasionally it is considerably lower than the trunnions so that the gun can be loaded while aimed at a considerable elevation. In such guns there is frequently attached to the base of the gun carriage a metal platform that revolves with it, and upon this platform one or two of the detachment engaged in aiming and firing the gun usually stand.

In the larger disappearing emplacements (Plates XIV to XX and XXII to XXV) the gun platform is very wide, and upon it are rolled the ammunition trucks, bringing the ammunition to the breech of the gun. One of the reasons why this platform has to be wide is to provide room for the detachments handling the sponge and rammer staves. Of course it is necessary to sponge the gun only occasionally, either after quite a number of rounds have been fired or after firing has ceased. The rammer, however, must be used every time the gun is loaded.

In the very early designs (Plate XIII) the loading platforms were very deficient in size and width. The movements of the detachment were quite cramped and consequently rapid loading was not possible. However, a short time later it became customary to build emplacements with very wide loading platforms. This permits the projectile truck to be pushed up to the breech of the gun on the run. When the truck strikes the breech it stops suddenly, but the projectile, by its inertia, bounds into the breech, and the ramming detachment soon become so skillful that they can place the head of the rammer against the base of the projectile as it bounds into the gun and can ram it all the way home without its actually stopping. To make such an action possible, an amply wide loading platform is necessary.

As an indication of the increase in the size of the loading platform, it should be noted (Plate XIII) that in the 1894 type of 10-inch emplacements the handrailing at the rear of the loading platform was but 34 feet from the axis of the gun well, while in the 1903 type (Plate XVII) this distance had been increased to 41 feet. In the 1903 type of 12-inch emplacement (Plate XX) the depth of the platform measured from the axis to the gun well to the handrailing in the rear is 52 feet. In the designs of the 14-inch emplacement (Plates XXII to XXVI) the loading platform is about 62 feet deep measured from the axis of the gun well to the foot of the surrounding earth slope, and in the 16-inch Panama emplacements this distance is 72 feet.

When it was discovered that the loading platforms that were built at the early batteries were not sufficiently large, it was, of course, impossible to widen them sidewise because of the concrete traverses that could not be moved. It was, however, possible to increase the depth of the emplacements to the rear, and under the appropriations for modernizing emplacements a large number of the loading platforms of the older emplacements were increased in depth. This was done at the same time that new hoists were introduced in these emplacements and new stairways built, and the net result was a great improvement in these old emplacements.

In designing a loading platform, the size of the gun well, of the loading platform, of the steps around it, and of the parapet wall in front of the gun and along both faces of the parapet must be fixed so as to accord with the Ordnance Department drawings of the gun carriage. In most of these details practically no choice is left to the Engineer Department, except as to the details of drainage, but the location and direction of the face walls of the parapet can be somewhat modified if desired.

The Ordnance Department drawing, showing as much of the details of the gun carriage as are necessary for the Engineer Department to have in designing the gun block and loading platform (which drawing is ordinarily known as the "Ordnance Department platform sheet") usually shows the distance of the end of the rammer staff from the axis of the gun well when the head of the rammer is placed against the base of the projectile on a truck pushed against the breech of the gun. To permit the projectile to be loaded "on the run," the depth of the loading platform must be 3 or 4 feet greater than required by the Ordnance Department drawing.

In designing the loading platform, a circle of the radius obtained in the manner just described is drawn with the axis of the gun well as a center. A tangent of this circle drawn parallel to the line of gun centers gives the position of the rear edge of the loading platform, and lines drawn parallel to the capital of the emplacement through the points of intersection of the circle with the face walls of the parapet gives the locations of the side walls of the emplacement. Where the loading platform is to be surrounded by sand side slopes and a parados, the locations of the foot of the side slopes and of the foot of the parados are given by the circle referred to.

The principal object of the loading platform is to provide a convenient place for the detachment while loading the gun. Its elevation should, therefore, be fixed primarily at that which will make the service of the gun most convenient. In the large disappearing emplacements, the axis of the gun in the loading position is practically horizontal and the elevation of the breech is practically the same whatever be the elevation at which the gun may be set for firing. It has been found that the ramming of the projectile is most convenient when the axis of the breech of the gun is from 46 to 48 inches above the loading platform. Consequently, the loading platforms are built at such an elevation as to place them about this distance below the breech of the gun when in the loading position.

For drainage purposes, as will be explained more at length on the chapter on dryness, etc., all loading platforms are given a slight drainage slope and some portions of this platform are, therefore, slightly lower than others. Since, however, the elevation of the loading platform is fixed by the convenience of loading the gun, the governing elevation must be that of the portion of the loading platform immediately below the breech of the gun in the loading position. The elevation of this part of the loading platform being fixed, the contours of other portions are arranged so as to provide proper drainage slopes.

When the loading platforms are so built as to drain away from the gun and the plane of weakness around the gun block is placed at the riser of the topmost of the steps connecting the loading and working platforms, the top of this topmost step is made the highest point and is placed at such an elevation that, allowing for the drainage slope, the circle on the loading platform under the breech of the gun as it revolves in azimuth will be at exactly the proper elevation for loading. Where, as in the design shown in mimeograph 109, (Plate XXII), the cylindrical surface of weakness comes directly over the air space, the intersection of this surface of weakness with the loading platform is the crest of the loading platform and the elevation of this crest must be so fixed as to place the circle under the breech at its proper elevation.

In the two-story batteries the loading platforms are a story above the ground and for the safety of the detachment, hand railings are placed along the rear of the platform. In one-story emplacements such hand rails are, of course, not needed. To avoid the nuisance of having water run over the rear edge of the loading platform of a two-story emplacement, a gutter with suitable drains is usually placed immediately in front of the hand railing.

Parapet Walls.

The front of the loading platform abuts against the parapet wall, and in the older emplacements the sides of the loading platform abutted against the concrete side walls of the emplacement. Ordinarily these front and side walls are made vertical for some 6 feet or so above the loading platform level. At about this elevation the walls usually project about 4 or 6 inches, forming what is called the "overhang." The face of the overhang is usually vertical up to near the top of the wall where it is finished off with a 45° bevel, 12 inches in the vertical and 12 inches on the horizontal. The overhang provides a convenient protection under which the electric light sockets and cables can be attached to the front and side walls. In the early emplacements the bottom of this overhang was made strictly horizontal but it was found that this permitted the rain water, running down the face of the overhang above, to pass in drops along the bottom of the overhang to the side wall and thence down the face of this wall. To avoid this it is now customary to place in the bottom surface of the overhang and about an inch from its outer edge a small groove made by nailing a strip of beading to the framing before the concrete is put in place.

Portions of the side and front walls of the emplacements are ferquently used as locations for telephone booths, for the openings of ventilators from the air passages and galleries below, for recesses for storing ammunition trucks, and, in the 14-inch emplacement (see mimeograph 109 and Plate XXII), for reserve projectile tables.

The front part of the side walls are also used in some emplacements (see mimeograph 109, Plate XXII) as locations for the stairways leading from the loading platform up to the top of the parapet.

Maneuvering Rings.

When it became necessary to mount the guns in the very first emplacements built, it was found that no arrangements had been made for the attachment of the blocks and falls necessary for handling the large pieces of the carriage and the guns. There was, therefore, introduced into emplacement construction the custom of inserting maneuvering rings. These rings are of wrought iron or mild steel and are made by bending into an annular form a piece of 1-inch to 1½-inch bar steel, the interior diameter of the ring being about 6 inches. The rings pass through the eye of a staple extending into and firmly anchored in the concrete front or side walls. At first the staples were allowed to project beyond the face of the wall so that the rings hung down against it. Subsequent designs, however, have shown these rings set in recesses.

Usually three maneuvering rings were installed in each emplacement but in large ones, especially those with the concrete side walls, five were provided.

Parapets.

The word "parapet" is derived from the Italian and in that language it means a protection in front of a man, rising up as high as his chest. Originally it referred to a protection for Infantry built only to such a height as to protect the bodies of the men behind it, while still permitting them to fire muskets over it. By extension, however, the word was later used to indicate any similar protection whatever its height.

For a while the attempt was made by certain military engineers to reserve the word "parapet" for its original meaning, an embankment for protecting Infantry, and to use the word "epaulement" for the higher protection used with cannon in siege and similar batteries. Strictly, this was not correct, for by its derivation epaulement means a protection shoulder high. In time, however, the attempt to use different words, one for an Infantry parapet and the other for an Artillery parapet, failed, and at present the word parapet is used for all protecting embankments, whatever their height; not only Infantry parapets some 4 or 5 feet high, but even the parapets in front of disappearing emplacements, which in some cases are 15 feet high. Occasionally even the term parapet is used to include the protection of concrete and sand in front of a magazine.

When, in the early nineties, work was begun upon the designs of our modern seacoast emplacements, it seems to have been considered by the designers that the main protection against hostile projectiles was to be obtained by a thick concrete parapet. Such a parapet was expensive and, for economical reasons, earth or sand was substituted for the concrete in the forward part of the parapet, because the same amount of protection could be obtianed at less cost with a comparatively thin concrete wall, having sand in front of it, than if concrete were used throughout.

Since that time our ideas have been changed. It has been found that when concrete is struck by a projectile it is shattered and that the scattering fragments of the concrete are exceedingly dangerous. Furthermore, the impact of a shell upon concrete is apt to cause the shell to detonate upon contact.

On the other hand, when a projectile strikes a bank of sand there are no large fragments of the parapet that can do any damage. Before the projectile can detonate, it is certain to penetrate some distance into the sand and when the detonation does occur the mass of sand above the shell serves to blanket the explosion and to reduce the scattering of the fragments of the shell.

Moreover, the damage done to concrete by the impact of projectiles can be repaired only by rebuilding the parapet and this takes time, whereas the damage done to an earthen parapet by the impact of projectiles or even by the detonations can be easily repaired by simply filling up the holes with earth.

For the above reasons, the sand part of the parapet is now regarded as the main protection and concrete is used only where there is not space enough for a sufficient quantity of sand, where it is necessary to have vertical walls, or where it is necessary to build an apron that can stand the blast of the guns.

In the fall of 1915, there was constructed at Fort Morgan, Ala. a test emplacement, and in March, 1916, this emplacement was fired at by naval vessels. The result of these tests was to show that naval projectiles striking a sand parapet, even in the exterior slope, will penetrate the sand but a short distance before being deflected upward and out, and that in a properly constructed disappearing emplacement, about the only vulnerable portion is the concrete blast apron within a few feet of the gun.

It was, therefore, decided to make another set of experiments to determine what was the best manner of constructing the part of the parapet immediately in front of a gun. The actual experiments took place at Sandy Hook in September, 1917, and the report upon these tests should be carefully studied.

Several types of parapets were tested and the result was, in general, to show that apparently the best type of construction for this part of the parapet was to build it of concrete, reinforced in three directions, this type having shown its ability to withstand a continued bombardment better even than a concrete parapet surmounted by a heavy plate of steel armor. It was shown that as each projectile struck the reinforced concrete parapet it loosened small fragments of concrete. These fragments, however, as a rule, were small, and the total amount knocked off by any projectile was not large. It was evident that in order to produce any effective result a large number of projectiles would have to strike in practically the same spot.

In connection with the designs of the recent emplacements built for the long-range 12-inch rifles, some studies were made of a new type of parapet to be composed of sand only and to contain no masonry whatsoever. These parapets were designed for guns mounted on barbette carriages capable of being fired at a high angle of elevation and placed in locations where the conditions as to depths of water in the probable area of fire are such that firing at a less elevation than 10° would probably never be necessary. It was proposed for such emplacements to move the parapet so far to the front that it would not be injured by the blast of the gun; to make it quite thick, and to build the interior and exterior slopes at the natural slope at which the sand would stand. The top of the parapet, usually called the superior slope, was to incline inward and downward at an angle of 10° toward the gun, and was to be at such an elevation as to be only a few feet below the trajectory when the gun was fired at the minimum angle of 10°. Such a direction for the slope of the top of a parapet is contrary to the usual practice. In order to provide for drainage, it is customary to give slight slopes to the tops of all parapets, and these slopes usually incline downward and outward in order to provide a clear field of view and of fire. With this new type of emplacement, the fire was to be indirect so no view was necessary. In fact, the principal object sought was concealment, and the higher the parapet the better the concealment. The parapet, of course, could not be high enough to intercept the trajectory, and by making the outer crest the higher, a better concealment could be obtained and the top would be more nearly parallel to the trajectories of the enemy's projectiles.

Although the plans of several batteries having parapets of this new type received the approval of the department, no such parapets were actually built. Before the actual work had reached the stage of parapet construction, it was decided to do away with parapets entirely so that the men at the guns might see the target and so the guns, if desired, might be fired at zero elevation.

Side Walls of Emplacements.

The adoption of the idea of relying upon sand, rather than upon concrete, as the main protection against an enemy's projectiles, caused a considerable modification in the type of battery construction. In all the typical batteries designed prior to 1909, the loading platforms were shown as having vertical concrete side walls. It was known, of course, that these side walls might be struck by a projectile coming from an oblique direction and passing a few feet over the crest of the parapet, but it was thought that projectiles striking a side wall at a slight angle would be deflected to the rear without being detonated and would do little or no damage. It has more recently been shown, however, that projectiles filled with high explosives and fitted with quick-acting fuses will probably be detonated by such a contact with a concrete side wall, and that this detonation may be sufficiently powerful to scatter the fragments of the shell about the loading platform.

To avoid this, concrete side walls were not used in the 1912 type of batteries, and for them were substituted gently sloping masses of sand. This was done with the idea that a projectile striking sand at a slight angle would probably be deflected away without exploding, or else would bury itself some distance in the sand before detonating.

Retaining Walls.

In more recent emplacement designs, retaining walls, except immediately in front of the loading platform, are not carried all the way to the top of the mass of earth which they retain. They stop some 5 feet or more below the crest of the earth in front, which, for this remaining distance, is sloped upward from the top of the wall. This was done because experience has shown that in most cases projectiles striking on a nearly flat surface of sand penetrate only a few feet before being deflected upward. Consequently, the tops of retaining walls when kept low will, in all probability, never be hit, and if so, will be damaged only at the top.

Amount of Protection to be Afforded.

When, in 1890, the Board of Engineers began to design our modern fortifications, the concrete which they prepared to use was to be made of Rosendale cement, and it was assumed that the protection given by such concrete against the penetration of projectiles was about twice as great as that offered by sand. In 1893 the board submitted a report to the effect that the amount of protection necessary in large emplacements against heavy naval guns was the equivalent of about 45 feet of concrete, or 90 feet of sand.

In 1896 they stated—

> It is assumed that the maximum cover of 70 feet of sand or its equivalent will afford sufficient protection for the guns, 90 feet for the magazines; this distance being measured horizontally at the level of the exterior crest. The vertical cover over the body of the magazines should be equivalent to 6 feet of concrete. The concrete wall in front of the gun should be at least 20 feet thick. In computing these equivalents 1 foot of concrete is regarded as equal in resisting power to 2 of sand or 3 of earth. Wherever concrete is used as cover against projectiles it is intended that as many bowlders or large rocks should be embedded irregularly in the mass as are consistent with its uniting into one monolith; the object of this being to deflect projectiles. This should be done even at the risk of increasing the cost.

It was upon the basis stated in this quotation that the protection afforded the magazines, as shown in the early mimeographs, was mainly designed, although, as was noted in the discussion of the different types of emplacement in the preceding chapter, modifications were occasionally made—the protection shown on the mimeograph being sometimes reduced somewhat below the standards stated in the quotation.

The concrete to which the Board of Engineers referred in 1893 and 1896 was concrete made with Rosendale cement. Shortly after the Spanish War, however, the use of Rosendale cement was discontinued, and Portland cement was thereafter used exclusively. This change increased the strength and the resisting power of the concrete, and from then on the resistance of 1 foot of concrete was considered to be the equivalent of about 3 feet of sand—an increase of about 50 per cent over the ratio adopted by the Board of Engineers for Rosendale concrete. Consequently, we find in the text of the mimeographs relating to the 1903 designs for 10-inch and 12-inch emplacements, the board adopting as the standard amount of protection:

> Horizontal protection, front of magazine, 15 feet of concrete, 45 of sand; equivalent to 30 feet of concrete.
>
> Horizontal protection, front of gun, 15 feet of concrete, 40 of sand; equivalent to about 28⅓ feet of concrete.
>
> Vertical cover over magazine, 10 feet of concrete.

In Mimeograph 109, showing the typical designs for 14-inch emplacements and prepared in 1908, the same standard was adopted, except that the vertical concrete cover of the magazine was made 12 feet of concrete instead of 10 as previously recommended.

In designing the Panama batteries the standard amount of protection given was the equivalent of 35 feet of concrete or 105 feet of sand measured in the horizontal. Against projectiles, with an angle of fall of 2°, the protection was decreased to 30 feet of concrete; for an angle of fall of 5°, to 26 feet of concrete; for an angle of 15°, to 21 feet of concrete; for an angle of fall of 45°, to 18 feet of concrete, with 12 feet of vertical overhead protection. These figures were based upon exposed concrete, but wherever possible sand was substituted for concrete upon a basis of 3 feet of sand being equal in resistance to 1 foot of concrete.

Since the Panama batteries were designed the Fort Morgan experiments have shown the great efficiency of sand as a protection against modern projectiles, especially in its tendency to deflect projectiles upward and outward. Apparently, therefore, the standard of protection given to the Panama batteries was somewhat excessive. Instead of providing 20 feet of concrete and 45 feet of sand in front of a magazine, it is believed that 10 feet of concrete and about 45 to 60 feet of sand would have been sufficient. Over the magazine the sand should be so distributed as to be never less than 10 feet thick, measured vertically, and 14 feet thick, measured at an angle of 45°. Moreover, the outer upper edge of the concrete in front of the magazine should be sloped to an angle of 45° for a distance of 5 feet or so. For overhead cover it is thought that 7 or 8 feet of concrete is sufficient, provided there is 10 feet of sand above it. Where it is not possible to get this thickness of sand the thickness of the concrete should be slightly increased.

One fact that will probably be noticed from a study and comparison of the older mimeograph designs of emplacements is that the amount of magazine protection provided was apparently dependent upon the size of the gun to be emplaced, the larger the guns the thicker the parapet. This was based upon the idea that the smaller batteries would probably be the natural target for the enemy's smaller guns, the medium caliber batteries for his medium caliber guns, and the larger batteries for his main armament. Consequently, the 3-inch emplacements were designed to withstand the fire of naval rapid-fire batteries. The 5-inch and 6-inch emplacements were designed to withstand the fire of 6-inch naval guns, and the large gun emplacements the fire of the largest guns carried by any ships that could approach the battery.

If we could be certain that a heavy projectile would never be aimed at or strike a smaller battery, this might do very well, and when the batteries are scattered and the probable range small, it might be safe to risk it, but where small gun batteries are located in close proximity to larger ones, the former may probably be struck by large projectiles aimed at the latter, and since the explosive of the magazine of even a small battery would be quite demoralizing, this portion, at least, of the smaller batteries should be given almost if not quite as much protection as those of the larger batteries.

Stones in Concrete of Parapets.

It was the custom in the first of our modern emplacements to place in the concrete of the parapet, especially in front of the magazine, large irregular shaped stones and bowlders, it being supposed that a projectile that might penetrate the concrete would be deflected at the surface of the bowlders. That is, the bowlders in the concrete were supposed to make it more impenetrable. In general, these bowlders cost more than the equivalent volume of concrete but, nevertheless, it was considered that they were of sufficient value to justify the additional expense.

The improvement in cement has made the bowlders no longer necessary, and this is especially true now that the sand is considered as the principal protection rather than the concrete. Occasionally, of course, large masses of stone may be available and can be placed in mass concrete at less expense than the equivalent mass of concrete, so that their use is economical, but in general it is considered desirable to use them only in foundation work and not in parapets or in front of magazines.

Sodding.

The necessity of having a clear field of fire for the guns and a clear sight from the observing stations in rear of the parapet, make it necessary to finish off the upper surfaces of the parapets of batteries in fairly regular planes having slight drainage slopes.

Of course, to prevent these slopes from being washed by rain, it is necessary to sod them. In our northern States these surfaces are sodded by actually placing sod. In the southern States, however, it is customary to plant little tufts of Bermuda grass at intervals and to keep them watered. These tufts soon spread rapidly and cover the entire slope with a nice sod.

In general, of course, grass will not grow well on bare sand. It is, therefore, customary to put between the sand and the sod a layer of soil or garden loam. When Bermuda grass is used it is necessary to cover over the sand with a thin layer of soil or clay.

During rainy seasons sodded slopes take care of themselves if the grass be occasionally cut and the weeds be kept out, but in long droughts the grass may die and it has, therefore, been customary for a number of years to install hydrants in convenient places in all batteries, the so-called hydrants consisting frequently of merely a faucet with screw threads for attaching hose. Not only do these hydrants serve for irrigation in the dry season but they also make it possible to wet the earth thoroughly before the guns are fired in target practice and thus to reduce the dust raised by the blast.

Camouflage or Concealment.

The custom of sodding the slopes of fortifications originated many, many years ago and at a time when the range of gun was so small as to make an attempt at concealment unnecessary. Unfortunately, in many places, such sodded slopes are quite conspicuous and invite attention at once to the existence of a battery.

This is, of course, to be avoided if possible, and some years ago instructions were issued that trees should be planted between the batteries and the shore with the idea that the trees would grow up and would eventually conceal the location of the battery. Occasionally, also, fine bushes, shrubs, and small trees were planted along the outer slopes of the batteries.

These lines of trees, however, unless there are a good many in the vicinity, invite attention to the fact that they are concealing something and presumably a battery. Where an entire post has trees in front of it or where a post is situated in the vicinity of improved land, these trees may be all right but a better form of concealment is to make the batteries appear from the sea as much like the surrounding country as possible.

This was especially attempted in the experimental emplacement constructed in 1915 at Fort Morgan.

This battery was located a half a mile or so from the main post. It was placed right in the midst of a line of natural sand dunes. Some of these sand dunes were bare, others were covered with irregular splotches of vegetation, bushes, wild grass, small trees, etc.

In building the emplacement care was taken not to injure any of the bushes or vegetation in the neighborhood. The emplacement itself was given a generally rounded contour not unlike that of most of the sand dunes. The sand used in the parapet was that taken from the vicinity and appeared just like the sand exposed in the dunes. In order not to make the area of bare sand around the parapet too large and thus too conspicuous, a number of bushes were transplanted from neighboring sand dunes and were made to grow on the parapet so that in its general appearance from the sea there was nothing to distinguish the emplacement from the sand dunes in which it was placed.

Unfortunately, it was found that the strong winds had a tendency to blow some of the sand away and some of it into the emplacement and around the mechanism of the gun. It was evident, therefore, that some method of preventing this was necessary and the method attempted was to cover over the sand in the parapet with burlap fastened to stakes driven at about 2-foot intervals. This burlap was about the same color as the sand and, therefore, was not conspicuous but it was soon found that the strongest winds sucked some of the sand through the burlap, and to prevent this, it was found necessary to give the burlap a coating of grout composed of sand and cement.

Unfortunately, such treatment can be considered as a temporary expedient only, since walking on the burlap had a tendency to tear it and in spite of its cement wash, it was of little durability. The problem of permanently fixing sand under these conditions is, therefore, not yet solved.

The attempts made to conceal this battery were so successful that the naval officers stated that at ranges of 5,000 yards they were unable to distinguish the parapet from the neighboring sand dunes, and this even after they had visited the battery and noticed its location with relation to the surroundings. They therefore requested that some mark be given them in order to show them at what they were to shoot. This was done by building a large target 12 feet by 12 feet immediately in front of the gun and by attaching red streamers to certain poles erected in the vicinity.

The concealment just considered is concealment from horizontal sight only. The modern development of air craft, however, requires the concealment from observers in the air also. The earthen surfaces of the parapet are not so difficult to conceal since they can be sodded or be otherwise made to resemble the surrounding landscape, but it is exceedingly difficult to conceal the concrete surfaces, such as the loading platform or the passage ways leading to it. These smooth surfaces are, of course, necessary for the operation of the Ordnance trucks and apparently can be concealed only by some form of manufactured camouflage or netting such as was generally used in France for concealing field guns. Whether or not such a method is practicable is a question yet to be worked out, but it is hoped that experiments will soon be made.

Communications.

The word "communications" is ordinarily used in a military sense to include the means which are provided for getting from one place to another. As used in connection with emplacement construction, it includes the corridors, galleries, passageways, stairways, ramps, ladders, etc.

The communications provided in early emplacement construction were, in general, not as convenient as might have been desired. They were not numerous and, in general, the corridors and passageways were too narrow. From time to time improvements have been made as will be noted by comparing the successive designs of the emplacements for the same sized guns, and more especially by comparing the earliest designs (Plate XIII) with the latest mimeograph designs issued by the Engineer Department (Plate XXII).

In the 1894 type of emplacements (see Plate XIII) the loading platforms of the different guns of a battery were not connected at all but were separate and independent. Consequently, there was no way of going from one to the other except by descending the stairs and ramps to the parade level and by climbing again up the ramp and stairs to the loading platform of the other gun. This was inconvenient not only as regards the movements of personnel but also as regards the possible movement of ammunition. If ammunition had been raised to the loading platform of one gun it could not be moved to that of another gun except by this roundabout way.

Consequently, we find that in the 1898 type of emplacements (Plates XV and XIX) the loading platforms of the different guns of a battery are connected by a corridor which passes in the rear of the traverse between the guns. Not only did this permit the commanding officer or members of the detachment to move readily from one loading platform to another but it also made it possible to roll quickly to one gun, ammunition from the loading platform of another. In this way there is provided a reserve alternative method of getting ammunition to any gun in case its own ammunition hoist should become disabled or temporarily out of order.

Not only were such corridors provided in new emplacements built during and after the Spanish War but, about 1903 to 1905, similar corridors were added to the older emplacements which had been built without connecting corridors between the loading platforms.

Such a corridor passes in rear of the traverse, and in front of it is the vertical concrete rear wall of the traverse, so that the corridor is quite well protected from the enemy's fire. The wall in the front of the corridor, therefore, became a very convenient location for the outlet or delivery table of the shell hoist. Incidentally, also, the wall immediately in front of this corridor was found a very convenient place for the Ordnance Department motor generator room, for telephone booths, for emergency powder recesses, and in 1908 and later designs, for the plotting rooms.

At first this corridor connecting the loading platforms was called by several different names, but after it became the usual location for the delivery table of the ammunition hoist, it became customary to call it the "truck corridor," because it was principally used for rolling the ammunition trucks from the ammunition hoist to the loading platform. In the early drawings, the truck corridors are shown as without roofs, but the desirability of having at least the delivery tables of the hoists protected from the weather soon became evident and small corrugated iron roofs were placed over the tables in many of the emplacements. In the 1898 and 1900 type plans (Plates XV, XVI, and XIX), splinter-proof roofs were placed over some of the corridors but not over others, and in the 1903 type plans (Plate XVII and XX) all of the corridors were shown as completely covered. This has been the rule since that time.

In the Panama batteries, since the ammunition is kept on the same level as the loading platform, ammunition hoists are not necessary, so the truck corridors pass directly from the loading platforms to the service ends of the shell rooms of the magazines. Where flank fire is not to be feared (see Plate XXIII), the truck corridor opens on the side of the loading platform close up under the front parapet, and thus passes into the magazine space approximately perpendicularly to the capital of the emplacement. The shell rooms and magazines therefore run fore and aft with respect to the capital of the battery. Where there are two emplacements of this type united structurally into a single battery, the two truck corridors are frequently connected so that a passage from one emplacement to the other is provided.

Where, however, flank fire is to be feared the truck corridor runs backward from the rear of the loading platform around to the flank and enters the magazine from the rear in a fore and aft direction, approximately parallel to the capital of the emplacement. (See Plate

XXIV.) In this case the service ends of the magazines and shell rooms of course open on this truck corridor, and, consequently, the length of the magazines and shell rooms is approximately perpendicular to the capital.

Where rear fire also is to be expected the rear of the magazine is carefully covered and the rear corridor or passageway leaves the loading platform through a parados. Consequently the whole of such a passageway is under cover. In all such cases the attempt was made to provide at least two passageways between the magazine and the loading platform, so that in case one was destroyed the other might be used.

In the earlier two-story emplacements the rooms on the lower floor usually opened directly upon a pavement or sidewalk. Subsequently, in connection with modernizing, the loading platforms were widened and extended over the pavements, being supported at the rear by columns. The pavements were thus converted into covered lower corridors communicating with the rooms on the lower floor. This arrangement having been found very convenient, we find in the 1903 type of emplacement (Plates XVII and XX) a similar lower corridor passing in rear of the rooms under the loading platform, and similar arrangements will be noted on the 1908 type (Plate XXII) connecting the hoist rooms of the different emplacements.

In the 1894 type of emplacements (see Plate XIII), it will be noted that there is an attempt at a communication between the magazines and the crane level. This communication was useful only for passing projectiles because the difference in elevation between the floors of the two levels was too great for persons to step up and no stairway was provided. In a few cases temporary stairways or ladders were subsequently added. These improvised stairways made it possible to go quickly from the magazine to the crane level whence it was possible, by means of the stairways already built, to proceed to the loading platforms. This method of communication proving quite useful, we find in all subsequent types of two-story emplacements a direct communication by means of a stairway between the magazine space and the loading platform. This communication usually opened on the wall in front of the loading platform, sometimes on the loading platform level and sometimes on the working platform level. (See Plates XIV to XX.)

In the 1903 type of 6-inch disappearing emplacements (Plate XI), a passageway intended for powder service was designed to pass in front of the magazines from the front corner of one loading platform to the front corner of the other. This interior and thoroughly protected passageway proved so useful that a similar passageway was provided in the 1908 type of 14-inch emplacement (Plate XXII), passing on the lower story completely in front of the magazine space, from one side of the magazine traverse to the other, and communicating by stairways with the working platforms of the two guns and through the long store rooms with the rear corridors of the lower story.

For access to the loading platforms, all of the older emplacement designs show stairways passing from the lower level up to the loading platform. In the 1894 type these stairways were quite inconveniently arranged. (See Plate XIII.) Improvements were made in later emplacement designs, but the stairways, as a rule, were located directly in rear of the center of the loading platform. (Plates XVI, XVII, and XX.) As has been stated in the preceding chapter, this central position has been shown to be an inconvenient location for the stairways, so in the 1908 type (Plate XXII) it was abandoned and two stairways, one on either flank of the loading platform, were used instead.

It is frequently necessary for an officer or some member of the detachment to go from the loading platform to the top of the parapet. Some of the earlier mimeographs (Plate XVI) provided ladders for this purpose, and most of the earlier emplacements constructed had these ladders. Such ladders were usually inconvenient, and in later batteries stairways are provided instead.

The return to the one-story type of battery, as in the Panama batteries, has, of course, done away with the necessity for the stairways formerly connecting the two stories of an emplacement, but it has thrown the battery commander's station, crow's nest, etc., very high in the air, and it has required the construction of special stairways leading to them. The method of doing this will be noted in connection with the designs of the Panama batteries. (See Plates XXIII to XXVI.)

In the Panama batteries, where the earth side slopes have superseded the concrete side walls, stairways leading from the loading platforms to the top of the parapet are not as necessary as they formerly were, since, when communication this character is necessary, a person can run up the earth slope. If this be considered undesirable, a concrete stairway can be built close up to the parapet wall.

Stairways, when needed, may be made of wood, metal, or concrete. Within the interior of emplacements, concrete stairs are the most convenient and have been generally used. The stairways on the exterior of an emplacement may be built of metal or of concrete. It would appear that, in general, metal stairways have been used, the treads being made corrugated or otherwise roughened, so as to avoid trouble from sleet. In the more recent emplacements in the tropics, however, all exterior stairways have been made of concrete, a popular type of construction being reinforced concrete in the form of cantilevers projecting from the rear faces of the batteries.

In the old types of fortifications constructed just prior to the Civil War and, in fact, for many centuries before that, communication between the different levels of a fortification was usually provided by ramps, up which the guns of the day, which were usually mounted on wheels, might be rolled. In the more modern fortifications, ramps are very seldom employed. However, in the 1894 type of 10-inch emplacement (Plate XIII) they are used for communication between the crane and the parade levels, while in the plans shown on Plates VIII and XVI, ramps are provided on the flanks of the battery for communication between the two stories. Very gentle ramps have also been sometimes used in modern batteries for communication between the loading platforms where, on account of the peculiar circumstances of the site, the different guns were emplaced nearly, but not quite, on the same level. Such cases, however, were unusual and can not be considered as standard.

Rooms, Magazines, etc.

In the fortifications built during and before the Civil War it was customary to build the main magazine in some secluded and thoroughly protected place, small service magazines, containing enough power for single actions, being usually installed in the traverses between the guns.

In designing the early modern emplacements there was too great a tendency to economy in magazine space, the magazines being small and somewhat inconveniently arranged, as has been shown in discussing the various types of emplacements. Not only were the magazines small, but in order to give them thorough protection they were hidden away in the body of concrete where they could receive no natural light and where ventilation was difficult. In hardly any other feature of gun emplacements has there been as much improvement from the early to the present types of emplacement, as in the character of the magazines and storerooms, in the amount of space allowed for them, in their convenience in location, in their ventilation and protection from dampness, and in the arrangements made for furnishing both natural and artificial light. This improvement is well shown by a comparative study of the successive types of emplacements.

The magazine taken as a whole consists of the powder magazines and of the shell rooms. The powder magazine, of course, requires the maximum amount of protection possible, the shell rooms not necessarily quite so much. Consequently, in a number of emplacements the sides of galleries and corridors and the space under the loading platform have been utilized for storing shells, although very frequently this has resulted in the serving of such shells being somewhat inconvenient.

In the more modern batteries, therefore, the shell rooms have been specially designed for this purpose and, except under the improbable condition of the supply of projectiles being much greater than can be stored in the shell room designed for them, it should not be necessary to utilize for the storage of projectiles any space not specially designed for this purpose.

In order to provide sufficient head room for the proper operation of the trolleys, the ceiling height of shell rooms where trolleys are to be used should never be less than 8 feet in 12-inch or smaller emplacements. For 14-inch emplacements, the Panama standard was 8 feet 6 inches and for 16-inch emplacements 9 feet. The standard height of powder rooms has been 8 feet, but if the single cartridge charge is to be adopted as a standard the ceiling height of 16-inch magazine must be made at least 9 feet 6 inches.

The ceiling height in 6-inch and smaller emplacements may, if necessary, be reduced to 7 feet 6 inches, but this is not desirable unless absolutely essential.

The early emplacements provided merely powder rooms and shell rooms. A little later storerooms for general purpose were provided, also power rooms. Still later it became necessary, in the larger emplacements, to provide motor generator rooms for the special apparatus provided by the Ordnance Department for the operation of the electrical elevating and traversing gears installed on the larger gun carriages. In some of the emplacements also, specially designed rooms were provided for taking care of oils and waste provided by the Ordnance Department for the preservation of the gun carriages. Some of the older emplacements provided what were known as "relocator" rooms for use in connection with fire control. In the more modern emplacements this room is known as the "plotting room" and will be further discussed in the chapter on fire control.

Latrines.

Seacoast batteries, as a rule, are located at some distance from the barracks in regular use and sanitary reasons require that latrines be provided either in the batteries or in their immediate vicinity. In the early constructions outside latrines were always provided, usually of temporary frame construction. These were frequently unsightly and in many cases soon became unsanitary. Consequently the custom later grew up of providing latrines in all new emplacements, certainly in all larger ones and usually in all smaller ones where they were not located in close proximity to large emplacements with sufficient latrine accommodation. It would appear to be needless to say that during the wintertime all plumbing is subject to damage by freezing unless the buildings or rooms be kept heated. This heating is not always possible in emplacements and, consequently, resort must be had at such times to special forms of frost-proof plumbing of which there are many varieties on market.

In addition to the latrines it is now customary to install in emplacements washbasins for the men and separate toilet facilities for the officers. In the Tropics, at least in the Panama batteries, shower baths also were provided.

In a few locations in the Panama fortifications, especially on the islands at the Pacific end of the canal, there was a question as to a possible insufficiency in the fresh-water supply. Arrangements were therefore made for the installation of two water-distributing systems, one for salt water and one for fresh water. Water for the showers and all flushing was, of course, salt, the fresh water being retained for use at the washbasins, for irrigating the slopes, and for washing out the batteries at certain places where it was thought that salt water might be injurious.

In this connection it should be noted that the sewers from the latrines should be kept carefully separate from the drains for removing rainwater or seep water only, this being done not only within the limits of the emplacements but also outside.

Quarters and Dormitories.

The question as to whether or not there should be provided in seacoast emplacements dormitories, kitchens, etc., for the garrison is one which has been much discussed. In connection with the design of the Panama batteries and especially the more isolated of these, sketch designs were presented to the Chief of Coast Artillery, showing how dormitories for the Coast Artillery detachment could be provided. After thinking over this matter he informed the Engineer Department that they would not be needed and that he considered it preferable to camp the detachments in the immediate neighborhood of the battery. In a number of the 12-inch long-range batteries constructed in 1918 the rear corridor of the battery has been fitted so it may be closed in and used as a dormitory, and in other cases special dormitories have been provided in a parados where one had to be built. In the turret batteries constructed on El Fraile Island in Manila Bay the Engineer Department has provided dormitories and all other provisions for the care and comfort of both the commissioned and enlisted personnel.

If it should be decided that the manning detail of the battery should in time of peace be quartered in the battery it is not improbable that barracks for the detachment could be constructed just about as cheaply in connection with the battery as elsewhere, but until the Artillery policy of this country changes it may be taken as extremely probable that in time of peace the troops will be housed and will live away from the batteries and under somewhat more comfortable conditions than could be provided in barracks intended for use mainly in time of war. Consequently it would appear that the provision of barracks or dormitories at the batteries for use in time of war only would be an expense which could hardly be justified, for in general there will be space enough in some of the spare rooms of the battery or its vicinity for at least some of the detachment on duty to sleep during war time.

The question as to whether in any particular case dormitory space should be provided in any battery is one that is to be determined by local conditions especially applicable to the case.

Keys and Locks.

The multiplicity of doors in emplacements, all of which must be provided with locks, naturally led to a complication in the question of keys. At first nearly every door had a different key, and this required of course that anyone desiring to enter or inspect all portions of a battery should take a large bunch of keys. The next step was to make the locks in a system with a master key, so that one key only would have to be carried. This was found to be unsatisfactory and a duplication of locks was next suggested so that one key might open all the locks in the battery. It was found best, however, to make a distinction between the locks of magazines and the locks of other rooms. Consequently it was decided to have all the locks of all the doors to the magazines of a battery duplicates of one another and therefore opened by the same key. Similarly the locks to all the other rooms were to be duplicates of one another but different from the magazine locks. This made it necessary to carry but two keys to get into all the rooms and magazines of a battery.

Additional complications were introduced later, however, when range stations were built for the battery. The range detachment was usually a more or less separate detachment from the remainder of the company assigned to the battery, and the responsibility for the fire-control property was placed on a different man, so that it was thought by some officers better to have a new set of locks for the range stations. Some battery commanders, however, prefer to have on the range stations a lock similar to the general lock of the battery.

Another disputed question connected with the subject of keys is what kind of locks should be used on the power room of a battery. The battery commander and his mechanic must, of course, have access to the power room in order to turn on and off the power for lights and motors and, on the other hand, the care of this power room rests with the Artillery engineer. If the same lock is put on the power room as on the rest of the battery, it will permit the Artillery engineer and his subordinates to enter any part of the battery. This was not thought to be advisable, so that in some cases it has been considered best to put a different lock on the power room.

Another important question was the number of keys to be furnished for each lock. It is, of course, important that too many keys should not be furnished, for if this be done it will be difficult to keep track of all of them and some may fall into the hands of improper persons.

In the older system, where each door had a special lock, two keys were usually furnished, one for the battery mechanic and the other for the use of the battery commander. When the keys were duplicated the same custom continued, two keys for each set of locks being furnished. However, complications soon grew up in this matter by the necessity in some cases of furnishing additional keys to range detachments. The question of the keys to the power rooms also gave trouble. In most posts, also, the post commander wanted to have a set of keys reserved for his own use and kept in the hands of the post adjutant, so the number of keys which should be furnished for different locks has not remained settled. (See mimeograph No. 64 and its supplements.)

There was a question also as to whether the Engineer officer, at the time of the formal transfer of a new battery, should turn over keys to the battery commander or to the post commander. The proper course is, the author believes, for him to turn over the full number of keys to the post commander, and leave with him the responsibility for their proper distribution.

Another debated question was the kind of lock to be used, whether it should be a mortise lock or a padlock. Many officers at first seemed to favor the mortise lock, as they are undoubtedly the safest.

Personally, however, the writer favors the padlock for a number of reasons. It has been found that in some doors the blast effect of the discharge of a heavy gun on mortise locks is to bend the bolts and make the lock difficult or impossible to open. If padlocks are properly installed, no such action is possible. Furthermore, the use to which any particular room may be put changes from time to time, and the system of keys desired by the battery commander is also subject to change. Padlocks lend themselves readily to such changes; mortise locks do not.

Another and perhaps more important reason still for preferring padlocks is that not infrequently an officer decides that he would like to inspect a battery or a room of a battery, when he does not have a key, or when he finds that it has been lost or has been misplaced. Experience shows that in such a case the officer is going to get into the battery, and in doing so a padlock can be forced without injuring anything else except the lock itself. A mortise lock can usually be violated only with severe injury to the door, and the cost of such repairs is much greater than the mere replacing of a padlock.

If padlocks are used, each padlock should always be attached by a chain, so that when not in use it will hang near its proper place and can not be mislaid.

Another question in connection with keys has frequently been brought up by the loss of a key. If it has been entirely lost no trouble can follow, but if it has been stolen or has fallen into the hands of an improper person he would be able to go where he should not. Some Artillery officers, therefore, as soon as a key has been lost, have asked, not for a new key, but that a new lock be installed. When each door had a particular lock, the replacement of this single lock was a minor matter, but where the loss of a key means that a whole set of locks must be replaced, the expense is not small, as will be readily understood when it is stated that in one of the batteries at Fort Monroe, 75 locks of one kind (all duplicates) were installed.

In selecting the particular kind of locks to be used in emplacements, it must be remembered that the locks are to be installed in locations where moisture is certain to be present, at least occasionally. Consequently, locks made of iron or steel, or having iron or steel parts, should not be used: Locks made of solid brass are best, but bronze locks are also permissible. However, in purchasing bronze locks, the district officer must be certain that the locks to be purchased are really made of solid bronze and are not really steel locks with merely a bronze finish. Bronze finished steel locks are on the market and are frequently known by the name of "bronze," but when such locks are exposed to moisture the dampness soon finds its way through the bronze finish, causes the steel below to rust, and the locks not only soon become unsightly, but frequently get out of order.

Where two or more different systems of locks are installed in an emplacement, the different systems must not be merely different combinations of the same variety of lock but must differ from each other as much as possible so that a mere glance at any lock will show instantly to which system it belongs. Furthermore, the keys for the different systems should also vary greatly and must differ so much that there can be no mistaking which key belongs to any lock.

Before being turned over to the Artillery, each and every key transferred should have attached to it a metal tag, stamped so as to indicate exactly to which battery and to which particular system the key pertains; such as "Parrott, General," "Eustis, Magazine," or "Church, Fire Control." It is also convenient to add to the tag, in addition to the names of the battery and system, a number, and this same number should be stamped not only on the key tag but also on all the locks belonging to the system. For convenience, each of the systems of locks at any fort should have a separate and distinguishing number and the Engineer officer should have in his office a record of these numbers for use in furnishing additional locks or keys.

The question of the system of locks to be installed and of the number of keys of each kind to be furnished is evidently one of administration proper, and all questions of this character should be decided by the Artillery authorities; in any special case by the post commander, and in cases of general policy by the chief of coast artillery upon the recommendation of the Coast Artillery Board.

The question of keys for batteries and other structures has lain dormant since the United States entered into the World War, largely because all the batteries and other structures have been in commission, the troops being kept habitually close to the batteries and sentinels being always on duty. However, with the return to peace conditions, it is to be expected that the question of keys will be again raised, and consequently the above historical data has been inserted, so that if any Engineer officers should be called upon to act in connection with the question of keys, they may know something of the history of the case.

Speaking Tubes and Voice Tubes.

Speaking tubes in emplacements are, of course, designed to allow oral communication between different portions of an emplacement. Occasionally, speaking tubes have been used in connection with fire control, but, in general, fire-control communication has been by telephone rather than by speaking tubes, and speaking tubes have been used for general purposes only and not for transmitting fire-control data.

In some of the very earliest emplacements speaking tubes were installed for talking from one loading platform to another or from a loading platform to magazines, etc. In the early batteries, however, the tubes, as a rule, were small, 1 inch and occasionally smaller pipe being used. These pipes were inserted directly in the concrete without any attempt being made to surround them by a sound insulator. Owing to the small size of the tubes, they were not effective at any great distance, and owing to the way in which they were put in the concrete they would gather up the rumbling due to the movement of trucks along the corridors or over the loading platform, or of the movement of the trolleys along the trolley rails. Consequently, whenever the battery was in use, there came from these speaking tubes such a roaring or rumbling as to make conversation through them extremely difficult.

It being found that the speaking tubes which had been installed were practically useless, their installation in emplacement construction fell, for a number of years, into disfavor.

However, some experimenting on this line was done, and it was shown by these experiments that by increasing the size of the tube, eliminating all sharp corners, and substituting easy bends instead, the speaking tubes could be made quite useful. Furthermore, it was found that the trouble due to rumbling could be largely eliminated by suspending the speaking tubes from the ceilings of rooms, galleries, air spaces, etc., and by insuring that when they passed through walls they did not actually touch the concrete of the wall.

Speaking-tube systems installed according to this new practice have been placed in the recent batteries constructed in Hawaii, Panama, and on the Pacific Coast, and are understood to work quite satisfactorily.

Not only have tubes been used for communication between two places, but occasionally a tube has been split into two branches, one running to a plotting room and the other to the battery commander's station above it, so that a person at the other end of the tube may talk either to the plotting room or to the battery commander's station or possibly to both at the same time.

To make such an arrangement successful, however, a carefully designed manifold must be placed at the points where the tube branches.

A "voice tube" is really a large speaking tube, but the term at present is restricted to the large pipe connecting a battery commander's station and the plotting room which, in modern construction, is always placed nearly vertically beneath the battery commander's station. The standard voice tube now used is an iron pipe 8 inches in diameter. Its upper end is about 4 feet above the floor of the battery commander's station and usually about 2 feet from one of its side walls. Its lower end projects a few inches below the ceiling of the plotting room and is usually located about 2 feet from a side or end wall of this room.

By means of this tube the battery commander in the battery commander's station, or his representative, can look down into the plotting room, can talk easily and deliberately to a member of the plotting room detachment, and can see his face also.

To prevent rain or trash dropping through the voice tube into the plotting room a removable cover is attached to its upper end.

In all cases where voice tubes have so far been installed they have been placed vertically or at least have been only very slightly inclined to the vertical and their lengths have been comparatively short.

As an illustration of the speaking-tube system installed in modern batteries, I quote the part relating to speaking tubes from the report of the designing engineer, submitting to the chief of engineers the design of some of the Panama 14-inch batteries:

> For intercommunication between the different parts of each battery and between the two batteries a comprehensive system of speaking tubes has been provided. Speaking tubes with extensions to the battery commander's station connect each plotting room with every other plotting room and battery commander's station, so that a man in any battery commander's station or plotting room can talk to a man in any other battery commander's station or plotting room.

The plotting rooms are connected by tubes leading through the information tunnel to terminals located on the left side of the front of each of the working platforms, 5 feet above the level of these platforms and at the foot of the stairs connecting the working with the loading platforms. It is understood that from these terminals a flexible extension is to lead to a headpiece carried by a man on the working platform of the gun carriage; but as this arrangement of flexible headgear appears to be somewhat awkward, an alternative has been provided by which these speaking tubes, instead of leading to the terminal just mentioned, may be carried into the gun well and to a point in the gun well near the Ordnance Department terminal box, and the Ordnance Department is now experimenting as to the possibility of further extending this tube by flexible connections to tubes on the gun carriage.

At the plotting-room ends of the tubes mentioned in the preceding paragraph extensions are had to the battery commander's station, and the connections are such that each gun is connected with both of the plotting rooms and battery commander's stations of its battery, so that the gun may be controlled from either of the battery commander's stations or plotting rooms of the battery to which it pertains.

In the truck corridors near the magazine and shell rooms are located the terminals of other speaking tubes, each magazine being connected with both of the plotting rooms and the battery commander's stations of the battery to which it pertains, so that the ammunition service of either emplacement may be controlled from either of the battery commander's stations or plotting rooms of its battery.

Other speaking tubes connect each plotting room with the power room.

All speaking tubes are routed as far as possible in the open air, except when they pass through walls, where they should be covered with a sound insulator. The standard size of speaking tube is 3 inches, except for branches, where 2-inch tubes are sufficient.

In the installation of speaking tubes in emplacements one matter that should not be overlooked is their drainage. In the earlier emplacements, when it was customary to place the speaking tubes right in the mass of concrete, it was not unusual for water to find its way into the speaking tubes through the joints of the pipes or in other ways. This water would, of course, tend to accumulate in low places and occasionally would completely fill some short lengths of the pipes forming the speaking tube, and would thus absolutely stop the passage of the sound waves.

With the larger pipes now used and the present method of suspending them in the air the accumulation of water in the tubes is quite rare, but, nevertheless, it is still possible that water may find its way into the tubes, possibly through their outlets or terminals. Consequently, it is well to provide for the drainage of the pipes by boring small drip holes at low places. Where a drip hole is placed in an air passage or at some other location where the dripping water can do no harm the hole may be left open. At other places it is well to insert in the hole a pet cock which can be opened for occasional drainage, habitually, however, being kept closed.

The standard size of the pipes to be used for speaking tubes is now 3-inch. Where, in the neighborhood of plotting rooms and battery commander's stations, the main tube is divided into two branches, 2-inch pipes are sufficient.

CHAPTER VIII.

MORTAR BATTERIES.

Mortars date back to almost the very beginning of the use of gunpowder, a mortar throwing stones high into the air by the explosive force of gunpowder being the natural successor of the older mechanically built engines which threw large stones and other missiles over the walls of fortified places. Consequently at the siege of Constantinople, in the middle of the fifteenth century, we hear of the use of large mortars throwing stone balls weighing from 700 to 1,000 pounds.

For some time after the siege of Constantinople the development of mortars seems to have almost ceased, attention being given rather to the improvement of direct-fire guns which were able to make breaches in masonry walls than to mortars whose function was to throw missiles over the walls.

A century or two later, however, the use of mortars again became quite general in connection with the sieges of fortified places, the mortars being used to throw explosive projectiles over the walls and into the interior of the besieged places for the purpose of doing material damage and, incidentally, of affecting the morale of the garrison. The use of mortars, however, seems to have been restricted to sieges, and their use against ships seems not to have been attempted.

The ships of that day were, of course, built entirely of wood, and their wooden sides could be easily penetrated by the direct fire of guns. It was, therefore, not necessary or desirable, in firing against ships, to resort to high angle fire falling upon the decks, especially since the fire of mortars was much more erratic than that of direct-fire guns using a comparatively flat trajectory. The chances of getting a hit with a mortar were, therefore, much less than with a direct-fire gun.

In this connection it is interesting to note that as early as 1809 the construction of a mortar battery at Bedloe Island, New York Harbor, was proposed as a means of preventing an enemy from anchoring in the upper part of New York Bay. Although as far as is known this was a unique example in the United States of the emplacement of mortars primarily for use against ships, yet it is to be assumed that there must have been a number of cases where the same thing was done abroad.

At about the time of the American Civil War an important change was made in naval architecture. Metal armor came into use for strengthening the sides of ships, and actual experience with the monitors, used during the Civil War showed that the sides of ships could be made almost impenetrable. It then occurred to certain engineers that the decks of vessels were as vulnerable as they had ever been, and that, therefore, it would be well to resort to mortar fire for dropping projectiles upon these unarmored decks. We thus find, in 1869, that the Board of Engineers submitted a report in which they advocate the introduction into our seacoast defenses of large caliber mortars. The following is quoted from this report:

> To prevent the occupation, as an anchorage, of a roadstead, there is nothing more effectual than the mortar. It is believed, though never yet extensively introduced for that purpose, that it may be made an efficient agent of defense against ironclads of the channels of approach to our cities and ports; and if so, its emplacement involves none of the embarrassing questions of iron construction. It is well known that there are no projectiles of which sailors have greater dread than those from mortars, and that the invulnerability of the sides of an armored vessel can be but very imperfectly extended to her deck. On the other hand, the difficulty of hitting by vertical fire an object of as small an area as the deck of a vessel is conceded. But when it is understood that considerable accuracy of mortar fire can be attained against stationary objects, such as vessels in position or arrested temporarily by obstructions, at distances not exceeding the width of most ship channels, and that the increased effect of a successful shot will in some degree compensate for inferior accuracy, as compared with the gun, the mortar will readily be accepted as one of the most efficient means of defense against the modern means of attack.

At about this time Congress was making small appropriations for battery construction, and from the appropriations made during the years 1870 and 1871, allotments were made for the construction of three seacoast mortar batteries, one in Boston Harbor, one in the Delaware River, and one at San Francisco.

The mortar batteries then constructed bore but little resemblance to the present typical mortar batteries, in fact they consisted merely of flat platforms built behind parapets some 9 to 12 feet high. For the large 13-inch mortars, these mortar platforms were 15 feet square. They were composed of two cross layers of 12 by 12 inch timbers placed in contact, and the upper layer of timber was covered with a wrought iron plate. In general, these mortar batteries had no parados and no side protection except the usual earthen traverses in which were placed the service magazines.

The Boston mortar battery, however, was constructed on an island, in a position such that it might become subject to the enemy's fire from several directions. Side and rear earth protections were, therefore, considered necessary for this battery, and as constructed it consisted essentially of three pits 16 feet deep and having earthen side slopes. The pits were about 40 by 50 feet on the bottom and each contained four mortars.

This battery was, in its general characteristics, a sort of anticipation of the type of mortar battery which later became the standard, but since it was the only battery of the kind constructed at the time it was evidently not considered as a standard type but as one suited to very special local conditions.

Shortly after the mortar batteries mentioned were completed, battery construction practically ceased in this country for nearly 20 years, not being resumed until about 1890. During this period the suitability of mortars for seacoast use was quite actively discussed.

Although it was admitted by all that mortar projectiles falling upon the deck of a vessel would undoubtedly penetrate and do great damage, their use was opposed by many on account of the inherent inaccuracy of mortar fire. To overcome this defect Gen. Henry L. Abbot, Corps of Engineers, who, during the Civil War, had commanded a mortar battery at the siege of Petersburg, proposed to group a number of mortars together and to fire them at the same time and with their axes parallel thus increasing the chances of making a hit. In other words, he proposed to adopt, in using mortars against ships, the same method used by bird hunters, who, instead of loading their guns with a single bullet, make use of a charge containing many small shot.

To illustrate his idea, Gen. Abbot, in the early eighties, constructed at Willets Point (now Fort Totten) a mortar battery consisting of four deep mortar pits placed with their centers on the corner of a rectangle, the pits being separated from one another by two traverses crossing each other at right angles. In each pit were placed four mortars and in the traverses were galleries for intercommunication, magazines, storerooms, etc. This was the forerunner of the seacoast mortar battery.

About this time the accuracy of mortar fire was much increased by substituting for the old stubby smooth-bore mortars a short-rifled howitzer. This made them much more useful for seacoast work and in 1888 the Board of Engineers submitted a report from which I quote as follows:

> The increasing importance of vertical fire in coast defense resulting from modern improvements in constructing, mounting, and serving mortars; the large number likely to be introduced into our seacoast defenses as soon as work is resumed, and the fact that local peculiarities of site exercise comparatively little influence upon the plan of a mortar battery, have led the board to consider the details of a typical construction and theoretical discussion of the same by Gen. H. L. Abbot, which, so far as practicable, shall unite desirable and exclude objectionable features. The result is presented by accompanying drawing No. 1, designed for a site exposed to an all-round fire and which requires no explanation except as to its general principles.
>
> Although rifling mortars, and mounting them upon carriages which admit of ready handling and pointing, has done much to increase precision of vertical fire, the chief reason which has brought the weapon forward so prominently of late is that, while the attack which they deliver upon the deck is one of the most dangerous that a ship can

receive, large numbers of them can be mounted at very moderate cost in such a manner that they can hardly be injured even by the most powerful naval guns of the day. The chief objection to them has been their lack of precision of fire as compared with that of guns of similar calibers.

But in addition to improving the ordnance itself, much may be done to increase precision of fire by constructing the battery upon proper principles. Many mortars should be mounted in compact groups, each group constituting, so to speak, a unit to be controlled and pointed as a single piece by a single officer. Under such conditions, fire against a nearly stationary enemy will be far more effective than is generally believed. To secure the greatest concentration of the mortars of each group without mutual interference, and without encroaching upon the space needful for bombproof cover, should be the governing idea in designing a battery for vertical fire.

Four mortars may be served in a single pit by providing a bombproof shelter for the cannoneers from which they can fire the mortars simultaneously by electricity.

Four such pits, containing a total of 16 mortars, will form a suitable group for the command of a captain of artillery. It remains to arrange the pits to fulfill the fundamental condition that all the mortars shall be fired with identical elevations, azimuths, and charges. On the one hand, the lateral and longitudinal separation of the pits must be sufficient to afford space between them ample for magazines, loading rooms, and bombproof cover for the garrison. On the other hand, the extreme distance between pits must be limited to the extreme dispersion of the projectiles of a single mortar; or there will be an area of safety in the middle of the field of fall. Lateral dispersion being much less than longitudinal dispersion, this condition fixes a much narrower limit for admissible separation of the pits in a direction across the plane of fire than in a direction parallel to that plane. Indeed, in a lateral direction, this extreme limit can hardly be avoided, but it is easy to secure a decided overlapping of the rectangles in a direction parallel to the plane of fire. As appears from the drawing, these conditions are fulfilled when the centers of the outer mortars in each pit lie on a circle 150 feet in radius, the extreme lateral separation being 140 feet, and the extreme longitudinal separation being 265 feet.

* * * * * * *

While this discussion illustrates the great advantage resulting from combining mortars in groups of sixteen, the board is well aware that there are localities where such a grouping will not be suited to the site. We are, nevertheless, of the opinion that they should never be mounted in groups of less than four.

A few years later, in 1893, Gen. Henry L. Abbot, Corps of Engineers, who from the very beginning had been one of the most ardent advocates of the use of mortars in seacoast defenses, wrote for the Artillery Journal the following:

Mortars in coast defense possess incontestable advantages.

(1) The blow is delivered precisely where armored protection is least effective and in a direction which threatens danger to the magazines, the engines, the boilers, and the other vitals of the ship covered against horizontal fire by the water and heavy armor; and even if these vitals are not reached by the projectile the explosion of its charge of 100 pounds of high explosive will occur in the shell trap above the protected deck where the secondary armament and the bulk of the crew are fully exposed.

(2) The mortar battery may usually be located where it is concealed from the enemy, and where no effective reply is practicable. This so materially reduces cost that the number of mortars may be multiplied without extravagant outlay and their comparative lack of precision thus be corrected.

(3) Another merit of vertical fire is that the force of the blow increases with the range instead of diminishing, as in horizontal fire, the vertical velocity within ordinary limits of practice being measured by the square root of twice the acceleration of

gravity into the fall. The latter may be taken roughly at one-fourth of the range for an angle of elevation of 45°. At 60° of elevation the fall is one-half greater (and the range one-tenth less), and at 75° elevation the fall is four-fifths greater (and the range one-half less) than at 45°. These vertical velocities unfortunately are not great, being below 1,000 feet, and hence the energy required for penetration must be obtained by using large calibers with their considerable weights of projectile. With our new 12-inch mortars these weights range from 625 to 1,000 pounds.

It may be noted in this connection that experience at Sandy Hook has shown that with elevations exceeding about 65° there is difficulty in causing the axis of the projectile to remain parallel to the trajectory, and hence the use of higher angles is not favored. It is also found that the service of the piece is facilitated by selecting one of five fixed charges of suitable grades of powder, and regulating the range by slightly varying the elevation between 45° and 65°, rather than by the old method of depending wholly upon a variation of the charge.

The extensive use of vertical fire in the siege of Petersburg by the volunteer artillery troops under my command, as well as the previous preparatory training the regiment received when stationed in the defenses of Washington, first drew my attention strongly to this kind of fire. The results achieved proved the mortar, even in the crude form then in service, to be one of the most effective weapons on the lines of the Army; but experience equally demonstrated that it required careful treatment to bring out its good points. Improved modes of pointing over that prescribed in the textbooks, systematic mixing of the powder for the day's firing to obtain uniformity of action, equalizing the weights of the shells, and many other points no longer necessary to mention in connection with the modern type proved to be essential to satisfactory service. One practical difficulty, however, was found to be inherent in the system, and it impressed itself upon the mind as something which should be corrected, even with the large targets usual in field service, before all the efficiency possible could be secured. For use against so small a target as a ship this difficulty would become still more important; it is simply the impossibility of regulating the pointing by individual gunners when many pieces are directed at the same object. In gun practice the short time of flight enables each gunner to perceive where his gun projectile strikes, and to regulate his pointing accordingly. With the long times of flight, characteristic of vertical fire this is no longer the case. Shells are falling so thickly around the target that with a flight of many seconds he can no longer distinguish which is his own shot, and his aim may thus remain uncorrected because he imagines that he is doing much better than is really the case. Where, as in the case of a siege battery, the target remains immovable this difficulty may in a measure be overcome by determining and recording for future use the pointing of each piece separately; but against a target shifting position like a ship, I am satisfied that no dependence can be placed on individual pointing. One man must regulate the firing of a whole group of mortars to secure satisfactory results.

These considerations suggest how the engineer may assist the artillerist materially by designing the battery so that the fire of many pieces can be controlled as a unit by a single officer, stationed where he can observe the impacts. The problem is simple, and has been solved to develop this principle.

For example, say, 16 mortars are grouped in a single square pit in close juxtaposition. Evidently all of them would call for a common pointing, which may be given mechanically by the gunners with the aid of a horizontal azimuth circle on each platform, with the lines connecting the zero and 180° point all parallel to each other, use being made, of course, of identical elevations and charges. Such a battery would fulfill the purely theoretical conditions of the problem, but any artillerist will see that its service would be impracticable, because the needful magazines and bombproofs and routes of supply for the ammunition would be lacking.

In actual firing from a group of mortars it is quite certain that the dispersion of the projectiles would differ from that indicated by these computed rectangles, inasmuch as the different mortars could never be served so as to give identical trajectories parallel to each other; but the greater and more irregular dispersion resulting from this cause would be of immense benefit, because the overlapping of the different zones would be disposed in a manner to cover more ground and with more uniformity. The great difficulty in all firing is to make the center of impact coincide with the target, and this is to a measure overcome by the certain wandering of the shots from their theoretical positions. Assuming that the pieces are well served with the assistance of modern position finders, these figures make it evident that no ship could remain at anchor at this range (4½ miles) with impunity.

But certain conditions other than ballistic are demanded to enable the gunners to perfectly perform their duties; these are met as follows in the batteries under construction:

(1) There must be ample room about each mortar for loading; this is secured with the adopted carriage when the four pintles of each pit are placed at the corners of a square 20 feet on the side.

(2) Bombproof cover must be furnished to protect the men from the blast at firing, and for passages for conveying the ammunition in safety from the magazines to the mortars; this is provided to the extent of over 350 running feet, 10 feet wide.

(3) Convenient magazine accommodations must be given; there are two, each with a floor space of 580 square feet, disposed at right angles to the long gallery, and with anterooms and entrances so placed that two adjacent pits can be served independently of the other two, without requiring the different detachments to pass each other in the gallery. Capacity over 100 rounds is provided, the shells (loaded but without fuzes) being stored chiefly along one side of the long gallery.

(4) The ammunition will be served on truck cars running on tracks, with overhead facilities for loading.

(5) The whole interior will be lighted by incandescent lamps, run by a small dynamo under bombproof cover.

(6) All firing, of course, will be done by electricity; and

(7) Where arrangements for resisting attacks by boat parties are necessary they will consist of a counterscarp 15 feet high, with a ditch 30 feet wide, flanked by counterscarp galleries at two angles diagonally opposite to each other. Two machine guns in casemates will thus sweep each of the four ditches. Musketry fire over the approaches will be obtained by field intrenchments on the top of the central covering mass, prepared by the garrison after the outbreak of hostilities.

To secure the highest possible accuracy with this system, care should be taken by the Ordnance Department to insist on well graduated azimuth and vertical circles, and any failure in this respect should cause instant rejection of the defective work. The engineer can not be too careful to place all the platforms horizontal, with the lines connecting the zero and 180° marks truly in the meridian. Of course, any other position for these lines would serve equally well for a single battery, so long as they are parallel to each other; but the true meridian is named in the instructions of the Chief of Engineers in order to assist the commanding artillery officer at a central station where the position of the enemy is supposed to be known, to designate the first trial azimuth to be used at any mortar battery in the harbor.

One of these batteries can be served either by volleys of 16 mortars, by volleys of four mortars, or by single pieces. The latter method will naturally be used in obtaining the exact range and azimuth after the position of the enemy is approximately determined by the position finder. The effect of the conditions existing in the upper atmosphere will thus be determined by actual trial, and the commanding officer will have every detail under his control, and will be enabled to bring into play the highest professional skill and good judgment. It is to be hoped that at an early day the completion ot several of these batteries will permit regular practice to be had by the artillery troops stationed in the neighboring fortifications, and that by this means the entire system may be put to a practical test. Practice over a land range would afford data of extreme value, as by marking the projectiles with a cold chisel, as was done in the preliminary training of my regiment in the defenses of Washington, it would be possible to discuss the trajectory of each piece separately, and thus obtain precious information respecting group firing which can no where be found in existing records. Indeed, experimental investigation in this new field can hardly fail to lead to useful conclusions as to the best modes of serving modern mortars.

Original of 1892 Type of Mortar Battery.

Modern seacoast battery construction was resumed in this country about 1891 and among the first batteries started were two mortar batteries, one at Sandy Hook, New York Harbor, and the other in the defenses of San Francisco, Calif.

The general design of these batteries was based upon Gen. Abbot's original mortar battery built at Willets Point, there being four mortar pits and four mortars in each pit. An outline drawing of one of these batteries is shown in figures 1, 2, and 3, Plate XXVII.

The mortar pits had their centers on the corners of a rectangle about 140 by 255 feet, the long direction of the rectangle being such as to pass through the center of the expected field of fire. The pits were separated from one another by earthen traverses whose directions were parallel to the sides of the rectangle and which intersected at the center of the rectangle. On the outside the mortar pits were surrounded by an earthen parapet of the same height as the traverses—that is, about 40 feet above the floor of the pits.

Each mortar pit was a rectangle 40 by 65 feet, the sides being parallel to the sides of the large rectangle and the longer dimensions being parallel to the longer dimension of the large rectangle. The centers of the mortar wells were placed near the front of the mortar pits (that is, the side toward the enemy) and were 20 feet from each other and 10 feet from the sides and front of the mortar pit. The rear of each mortar pit was finished as a paved platform upon which the projectile trucks could be maneuvered.

The two mortar pits at the front of the large rectangle were connected by a cross gallery 8 feet wide extending from one pit to the other, through the long center traverse, this gallery being parallel to the shorter sides of the rectangle and being located so as to connect the rear of the two front pits. A similar gallery connected the rear of the two rear pits.

The center points of these two cross galleries were connected by a long central gallery located in or under the long central traverse. This long central gallery was 10 feet wide and had extensions at the front and at the rear beyond the front and rear cross galleries.

This long central gallery was intended, first, for communication, and second, as a storage place for projectiles which were to be stored four or five deep in tiers close to the sides of the long gallery, the points against the side walls and the butts lying along the sides of the somewhat narrow passageway which was left.

The space in and under the central cross traverse was utilized for powder magazines, of which there were two, 58 by 10 feet. There were also two powder handling rooms and two other rooms which could be used for general storage or for power purposes.

To the ceiling of the long gallery were attached three trolley rails, one on either side over the centers of gravity of the projectiles which were stored along the sides of this gallery, and the third along the middle. The side trolley rails were intended for handling projectiles, the trolleys running on these rails being provided with differential blocks by which the projectiles could be raised to the height desired. The central trolley rail was for the purpose of handling powder.

The fundamental idea upon which this type of mortar battery was based was that, in general, the whole 16 mortars should be fired in a salvo, and in rapid fire this required that the 16 mortars be loaded at once. This meant that the 8 projectile trucks for the 8 mortars at the front end of the battery would be loaded at the same time at that end of the long gallery—that is, four for each trolley rail; and similarly for the 8 projectile trucks for the 8 mortars at the rear end of the battery. To accomplish the handling of these projectiles with this speed it was necessary that there be 4 trolleys on each track at each end of the battery. Each of these trolleys would be placed over a projectile, the projectiles would be raised with the differential blocks as high as necessary and the trolleys would then be rolled until they were over the trucks. It is evident that the projectiles for the farther trucks had to pass over the intermediate ones. When over the proper trucks the projectiles would be lowered into them and then pushed to their respective mortars.

This required that 8 trucks be loaded at the same time in the small contracted space at one end of the long gallery, where there was little room to maneuver the trucks around and, as a result, the projectile service was slow and inconvenient.

Nor was the powder service much more convenient. For the handling of the powder for the 8 mortars at either end of the battery, a low platform was used, carried by trolleys running on the center trolley rail. This platform was long enough to carry eight charges of powder. It was pushed near the entrance to the magazine and the powder charges would be loaded on it. The platform was then pushed to the end of the gallery whence the powder was to be carried by hand to the mortars.

Experience with the first mortar batteries soon showed that they had a number of important defects. The pits were too small and too cramped for the rapid loading of the mortars. The use of the long galleries as storage places for projectiles interfered with free intercommunication, consequently the ammunition service of these batteries was slower than was desired.

The worst trouble experienced with these batteries was, however, the blast effect. The discharge of the mortars, especially when all four in one pit were fired at once, had a tendency to drive out of the pit all the air that was in it, and since the pits were closed on all four sides the outside air could not readily flow in to fill the partial vacuum created. From this vacuum in the pits a wave of rarefaction was started which ran into the galleries, corridors, and rooms of the traverses, doing great damage there, blowing doors off the hinges, destroying electric lights, and causing considerable discomfort to the personnel. Incidentally, also, the result of this blast would, not infrequently, cause the earth of the steep side slopes of the pit to slide into the pits.

In the earliest mortar batteries, the mortar pits were surrounded by vertical walls about 3 feet high. On top of these walls there was a berm, and from this berm the earth sloped up with the steepest slope at which it would stand. In some of the batteries built a little later, the vertical walls were made from 10 to 12 feet high, with earth slopes above. This raising of the side walls of the pits made it still more difficult for the air to get in to fill the partial vacuum caused by firing the mortars, and it was in the batteries built in this latter way that the earth slopes were most readily destroyed by the blast effects. In fact, in a number of these batteries, it became necessary before stability could be insured, to abandon the use of sod on the slopes of the pits and to revet these slopes with a concrete covering all the way to the top.

1894 Type of Mortar Battery.

In the meantime it had been discovered that the accuracy of the new mortars was greater than had been anticipated and that the dispersion of the shots was much less than had been expected. Consequently it appeared that greater accuracy would be obtained if, instead of aiming all 16 mortars of the battery with their axes parallel, a special setting should be used in each pit.

When the system of aiming the mortars of each pit independently was adopted, there was no longer any reason for adhering to the rectangular distribution of mortar pits, and consequently, in several of the new batteries which were begun about 1894, or shortly thereafter, the pits, instead of being placed on the corners of a rectangle, were placed in a line normal to the main direction of fire. Figures 4 and 5, Plate XXVII, show the ground plan of one of the batteries of this type, which we may call the 1894 type of mortar battery.

In this arrangement, the protection provided for the pits on the side toward the enemy becomes a long parapet extending along the front of the entire battery, and the space within and under this parapet is utilized for magazine and storage purposes. The entrances to the magazines are through doors opening at the left side of the front of each pit, and the space immediately in front of each of these doorways is widened out into what is called a lobby.

Each pit is separated from the adjoining pits by a short fore-and-aft traverse extending backward from the front parapet to beyond the rear of the pits. In plan, the rear of each traverse is rounded off and the rear slope is, therefore, conical. To the front and on both sides, the pits are finished off with the usual vertical concrete walls with earth slopes above the tops of the walls, but to the rear all protection is omitted thus leaving the pits open in that direction and permitting the easy inflow of air when the mortars are fired. This diminished the blast effect to a considerable extent.

The space within the parapet in front of each pit, and part of the space in front of the traverse to the right of the pit, is utilized as the magazine space, so that each pit has its own shell room and its own powder rooms. The shell rooms are immediately in front of the pits and the powder rooms are in front of the shell rooms. As the shell rooms pertaining to the four pits are interconnected by galleries, each shell room with the next, there is provided under the parapet a continuous passageway from one side of the battery to the other.

The projectiles are stored along the two sides, that is, the front side and the rear side, of the shell room, with a trolley rail over each. At the inner end of each shell room, these two trolley rails are united into one by a rail making a half circle, and, at the end of the shell room toward the lobby, both trolley rails extend into the lobby and to the outer door of the lobby, where they end.

Since at any time but four projectiles, one for each mortar in a pit, have to be placed on trucks in each lobby, only two projectiles have to be handled on each trolley rail, which makes the loading of the trucks simpler and more rapid than in the older or 1892 type of battery where four projectiles had to be handled on each rail.

The powder magazines are parallel with and lie in front of the shell rooms. Each powder magazine consists of two rooms opening into each other, a storage room and a rehandling room, the latter for use in preparing powder charges of the proper weight. The rehandling room opens into the lobby, so that in this type of battery the powder does not have to be carried between two long lines of projectiles as in the original type. The powder service is, therefore, much simpler and more satisfactory.

The drawings of this type of battery show a relocating room, and opening from it, a small concrete tower containing a spiral staircase leading up to a small crow's nest built in at the highest point of the battery. The relocating room is so situated that no daylight can reach it and has but little ventilation. In practice, these rooms were found to be damp and were practically never used for the purpose for which designed. The crow's nests, likewise, were found to be comparatively inaccessible and were soon abandoned.

The plans of this type of battery show also two connected power rooms situated like the relocating room, in a damp and badly ventilated place. The power rooms were also found to be too dark and damp for use, and were shortly abandoned for other rooms specially built outside of the battery proper. No air passages or other arrangements for preventing dampness are shown on the plans or were installed in the batteries of this type.

The most serious trouble experienced in this type of battery has been the severe blast effect. The entrance to the lobby, as will be noted on the drawing, is in front of the pit, and if the mortars are fired toward or approximately toward the front, their lines of fire pass almost directly over this entrance to the magazine. As a result, the blast effect in the magazine space, although not as severe as in the original type of battery, is yet too great for comfort and has frequently done considerable damage.

1898 Type of Mortar Battery.

In 1898 there were published, as Mimeograph 27, the designs of a new type of mortar battery, outline drawings of which are shown in figures 1, 2, 3, and 4, Plate XXVIII. As by this time it had been decided that 16 mortars were too many to be handled satisfactorily as a single tactical battery, this 1898 type is based upon the idea that the tactical battery shall consist of eight mortars only, that is, two pits with four mortars in each. As in the 1894 type, the pits are placed in a line perpendicular to the general direction of fire. The pits are, however, considerably larger than in the 1894 type, being in plan about 67 feet by 71 feet, but like the 1894 type, the pits have, on the front and flank sides, vertical concrete walls with earth slopes above. To the rear the pits are left open.

Instead of utilizing the space under the parapet for magazine and storage purposes, as is done in the 1894 type, use is made of the space under the central and two flank traverses. In each of these traverses long fore-and-aft walls extend nearly the whole length of the traverse, dividing the interior space into long rooms which open at the rear on covered corridors. These corridors are closed at the sides but are entered from the rear through wide doorways. With this method of construction, the rooms in the traverses are well protected from the effects of the blast and the blast effects in them have been practically negligible.

The rear parts of two of the central long rooms of the central traverse and of the most distant long rooms of each of the flank traverses are designated as powder magazines, there being a powder magazine for each two mortars instead of for each four mortars as in the 1894 type. However, the powder magazines are not divided as in the 1894 type into storage rooms and rehandling rooms and this is a defect that later had to be corrected.

The long room next to each powder room is used as a shell room, and, in front, this shell room extends around so as to utilize for storing shells the front part of the long room of which the rear part is used as the powder magazine. There is thus provided a very capacious shell room for each two mortars.

As is usual, the projectiles are stored along the sides of the shell rooms and over each pile of projectiles there is a trolley rail. At the rear, the trolley rails extend not only to the doors of the shell rooms but completely across the ceilings of the corridors and even as cantilevers well out from the rear face wall of the corridor. The projectiles are raised by the blocks of the trolleys, are then moved on the trolley rails out to near the end of the outside extensions, and are there lowered into the trucks. Since in this type of battery there is a shell room for each two mortars and there are two trolley rails in each shell room, there is a trolley rail for each mortar and only one projectile at a time has to be loaded from each rail.

The drawings show the long rooms on the left sides of the central and of the right flank traverse as "bombproofs." It was intended that as soon as the mortars were loaded, the personnel would take refuge in these bombproofs and in this way might escape the blast effect and at the same time be sheltered from the enemy's projectiles. Small rooms in rear of the bombproof are designated as firing rooms, it being intended that the firing cables should be led into these rooms and that the firing magneto should be operated there.

The plans show also a small observing station or crow's nest on the top of each of the flank traverses and a relocating room located on the lower level near the foot of the stairway leading up to each of these crow's nests.

Two power rooms, one for the generating plant and one for a storage battery, are provided in the left-flank traverse. Six-inch blind air spaces are provided as a partial attempt to reduce condensation.

The type of battery just described remained the standard in this country for quite a number of years and a number of batteries were constructed on these plans. From experience, a number of defects were developed and, as a result, slight modifications in plans were made from time to time. Among the defects that may be mentioned the most important appeared to be the small size of the powder rooms, as compared with the shell rooms, and the omission of the rehandling rooms. Furthermore, it was found that the attempt to diminish the blast effect had been somewhat overdone and that the powder rooms and shell rooms were a little too inaccessible. They could have been made more accessible by opening the corridors on the sides, that is, directly into the pits. Special bombproof rooms for the personnel were found to be unnecessary, as there was ample space in the corridor or in rear of the traverse for the detachment to stand in as the mortars were fired.

1906 Type of Mortar Battery.

The defects found in the 1898 type of battery were corrected from time to time in the detailed plans of the batteries built according to that general type, and finally, in 1906, these improvements were embodied in new plans which were published as a supplement to Mimeograph No. 27. The ground plans of this type are shown in figure 7, Plate XXVIII. These new plans, which may be called the 1906 type of mortar battery, hardly differ from the 1898 plans sufficiently to be designated as a separate type and might be considered as a variation of the 1898 type.

The two types resemble each other closely, the main difference being in the arrangement of the rooms in the traverses. In the 1898 type there are 10 long rooms altogether, and these are irregularly distributed among the traverses, while, in the 1906 type, there are 12 such rooms, distributed 4 in each of the 3 traverses. The four long rooms next to the pits are used as shell rooms, the whole of the next four rooms are used as powder magazines and each powder magazine is divided into two parts, the front part being intended for storage purposes and the rear for rehandling purposes. The two outer long rooms of the flank traverses are used for miscellaneous purposes, as storerooms, guard rooms, officers' rooms, and power rooms. No relocating or plotting room is provided, as at the time these plans were prepared plotting rooms were usually provided in connection with the primary observing stations. The corridors are made quite open to the rear, their roofs being supported at the rear by columns only. To the flank, the corridors open directly on the loading platforms.

The greatest improvement shown in the drawings of the 1906 type is the provision of shell tables at the corridor ends of the shell rooms. The one slow and laborious step in handling projectiles is raising them from the floor to the height of the trays of the projectile trucks. This is done ordinarily by means of the differential blocks of the trolleys, and the work is laborious and, if done rapidly, exhausting. To avoid this there is provided in each shell room of this new type of mortar battery two shell tables located at the rear or corridor end of the shell room, one table being located under each trolley track. These shell tables, each of which will hold 12 projectiles, are built of such a height as to permit the projectiles to be rolled from the tables directly into the trays of the shell trucks, and each table is provided at its corridor end with an escapement which, when not in use, will keep the projectiles from rolling off of the table and which, when operated, will permit one projectile at a time to be rolled onto the truck.

The main mass of projectiles is stored in piles in the front part of the shell rooms from which they are to be moved by trolleys to the shell tables. It is assumed that an engagement will find the shell tables completely filled, and as the projectiles are carried from the tables to the guns they are to be replaced by others brought from the piles in the front parts of the shell rooms. By making use of several trolleys on each trolley rail and with a sufficiently large detachment, these projectiles can be raised and can be placed on the shell tables without undue physical strain on the members of the detachment.

Although not shown on the drawings on Plate XXVIII, the mimeograph plans of this type of battery (supplement to mimeograph 27) showed an observing station or crow's nest on the top of each flank traverse and a small battery-commander's station on top of the rear of the central traverse. This station had concrete walls and a concrete roof and was reached by stairs leading down to the rear. No battery-commander's walk is provided. The mimeograph drawings show also mortar booths to the rear of one flank of each pit. These booths, which will be described in the chapter on fire control, are shown in figures 5 and 6, Plate XXVIII.

No air passages were shown in the plans, but the mimeograph drawings showed numerous ventilation openings connecting the various rooms and passing from some of the rooms to the outside air.

For several years after the publication of the supplement to mimeograph 27, but few mortar batteries were constructed and, consequently, batteries of the 1906 type are not very common. However, the shell tables, description of which was included in the same mimeograph, were added in a number of the batteries built previously in accordance with the 1898 type plans.

1912 Type of Mortar Battery.

All of the types of mortar batteries heretofore discussed were designed for 12-inch mortars. By about 1910, however, it had become evident that the 12-inch mortars were not sufficiently powerful nor had they sufficient range, even when the light, or 700-pound, projectiles were used. The Ordnance Department, therefore, began the design of a 14-inch mortar and of a carriage for it. As soon as the preliminary drawings of the 14-inch mortar carriage were received in the office of the Chief of Engineers, the Engineer Department began the work of designing a mortar battery for these 14-inch mortars.

Meanwhile the design was modified to a 12-inch mortar, 15 calibers long, and the designs for the batteries were modified to correspond. These batteries were first built in Panama and this type is therefore often mentioned as the "Panama" type.

In the meantime, experience with the older mortar batteries had shown that the simultaneous loading and aiming of four mortars in a single pit is somewhat difficult. To reach the front mortars the projectile trucks have to be pushed past the rear ones, and when the mortars are pointed in certain directions it is difficult to so maneuver the projectile trucks as to reach the breeches of the front mortars. To avoid injuring the men as the result of blast, no mortar in a pit can be fired while any other mortar in the same pit is being loaded and the rate of firing the mortars is, therefore, dependent upon the rate of loading the mortar which is the most difficult to get at. Consequently, the rate of fire possible with four mortars in a pit was found to be too slow.

As a result of this, it had become customary to use only two of the mortars in a pit at a time, preferably the rear two. In some cases, even the front mortars had actually been removed from the pits, leaving the rear two mortars only.

Incidentally, the increase in the length of the mortars had resulted in an increase in the accuracy of mortar fire and it now appeared unnecessary to continue the practice of firing as many as four mortars at a time at a single target. For this purpose two mortars appeared to be sufficient and it was, therefore, decided that in the new 14-inch batteries but two mortars would be placed in a pit and that they would be placed side by side. It further appeared desirable to provide a fire control installation which would permit each pair of mortars to be fired independently.

However, to maintain a sufficient volume of fire it appeared to be advisable, as a general rule, to retain eight mortars in a group, even though for tactical purposes the group might be subdivided.

To emplace eight mortars in a line and to locate the shell rooms and powder magazines in the traverses between the pits, as had been done in the 1898 and 1906 types (Plate XXVIII), would result in making the battery unduly wide. Furthermore, the increase in the range of naval guns and in the angle of fall of naval projectiles made it appear undesirable to continue the practice of storing powder in the traverses. Consequently, there was a return to the idea of utilizing the front parapet for magazine space as had been done in the 1894 type of battery. (Plate XXVII.)

The particular trouble that had caused the abandonment of the 1894 type of mortar battery had been the severe blast effects in the magazine, due to the fact that the doors of the magazines were located in the front walls of the pits, and therefore in front of the muzzles of the mortars when fired in the most usual direction. This difficulty had been avoided in the 1898 and 1906 types (Plate XXVIII), by placing the entrances to the magazines rearward of the pits. Consequently, in this new type of mortar battery, it was decided that, though the interior of the front parapet should be utilized as magazine space, the entrances to the magazines should be from the rear of the pits through the traverses, which had to be provided in any case to reduce the possible damage from enfilade fire.

Outline drawings of this 1912 type of mortar battery are shown on Plate XXIX, these drawings being based upon the general plans for this type of mortar battery and not on the plans of any particular battery. Although the general plans showed a battery of eight mortars located two in each of four pits, it was expected that for tactical purposes the structural battery of eight mortars would be subdivided into two tactical batteries of four mortars each. In fact, in all cases where structural batteries of eight mortars have actually been built, they have been subdivided tactically, to the extent even of giving each tactical battery of four mortars a special name, and of assigning to it a separate tactical organization of troops.

The mortar pits, which are separated, one from another, by traverses having splinter-proof concrete roofs, are 75 feet wide by 45 feet deep, measured from the front wall to the rear of the pit. The two mortars in a pit are emplaced 30 feet apart, center to center, and the center of each is about 22½ feet from the front wall and from the side wall of the pit.

The space within and under the front parapet is utilized for magazine purposes. The shell rooms are immediately in front of the pits and are separated from them merely by a concrete wall of such thickness as would appear necessary for protection. The powder magazines are in front of the shell rooms.

Due to the great width of the pits and the fact that there are but two mortars in each pit, the width of the mortar battery is now sufficient to make it possible to provide a shell room and a magazine for each mortar, instead of one for each two mortars, as in the 1896 and 1906 types (Plate XXVIII), and one for each four mortars as in the 1894 type. (Plate XXVII.) In each of the traverses there is a gallery which, at the rear, opens to the side on the mortar pits and, in front, extends forward as far as the front walls of the powder magazines. The shell rooms open on these galleries, and as, at their inner ends, the two contiguous shell rooms run into each other, there is provided through the shell rooms a continuous covered passage way from one side of the battery to the other.

Each powder magazine is divided into two rooms, a storage room and a rehandling room, the two being connected by a door. Each rehandling room has an additional door that opens on the front end of one of the galleries. For convenience in passing from the storage room of one magazine to the storage room of the contiguous magazine, a doorway is shown between them, but it is intended that this doorway shall be closable by two heavy solid metal doors so as to decrease the danger of an accidental explosion in one magazine being communicated to the next.

In the 1906 type of mortar battery (Pl. XXVIII), there had been introduced the idea of placing at the service ends of the shell rooms, shell tables for storing a limited number of projectiles ready for instantaneous service. The introduction of these tables had simplified the projectile service of mortar batteries, consequently this same idea is retained in this 1912 type of mortar battery. In fact an improvement is made, for instead of having but one shell table for each mortar, two shell tables are now provided for each.

During the interval between the adoption of the 1906 type of mortar battery and the preparation of the plans for the 1912 type, it had become customary for the Ordnance Department to furnish to all mortar batteries several different types of projectiles; heavy projectiles for short ranges, light ones for long ranges, projectiles having thick walls for piercing deck armor, and projectiles having thinner walls and high explosive charges for use against cruisers whose deck armor protection is but slight. The shell tables provided in the 1906 types of mortar battery, that is, one shell table per mortar, had simplified to a considerable extent the projectile service of the mortar battery as long as a single type of projectile had to be used, but it appeared that this system would not be thoroughly satisfactory in case it became necessary, in the middle of an action, to change from one type of projectile to another.

In order that a rapid change may be made as easily as possible, it was decided to provide in the new type of mortar battery, two shell tables for each mortar, this being rendered easily possible since there is now a shell room for each mortar instead of one for each two mortars as in the 1906 type. It is assumed that these two shell tables will be loaded with different types of projectiles, one table being used for the type actually being fired and the other table having placed upon it projectiles of that type which will most likely be called for if a change in type is desired. If, therefore, the tables are used in this manner and it becomes necessary in time of action to change from one type of projectile to another, all that is necessary is for the projectile trucks when coming for new projectiles to go to the other table.

Each shell table is fitted at its gallery end with an escapement of the usual form, which permits one projectile, and but one at a time, to be rolled from the shell table into the tray of the truck. When loaded, the truck is pushed through the gallery to its rear end, and thence, at the proper time, to the breech of the mortar. When the projectile has been rammed into the mortar, the truck returns through the gallery to the proper shell table to be reloaded with a new projectile.

The galleries in the traverses which lie between two pits are made 17 feet wide because along these galleries there have to be pushed trucks pertaining to two mortars. In the galleries of the flank traverses through which the trucks of but one mortar have to go, the width is made but 13 feet. The widths here stated are those now standard, but in a few of the earlier batteries of this type actually built the galleries were made slightly narrower.

While the plans of this type of mortar battery were in preparation, serious study was given to the question as to whether the shell tables should be placed at the gallery ends of the shell rooms and the trucks should be loaded there and be pushed through the galleries, or as to whether the shell tables should be located at the rear ends of the galleries. Some officers were in favor of one method of ammunition service and some of the other. Finally, however, it was decided, with the assent of the Chief of Coast Artillery, that the system shown on the plans should be adopted.

The projectiles are normally to be stored in the portions of the shell rooms inward from the shell tables. There are to be two rows of projectiles, one near the front and one near the rear side of the shell rooms, the projectiles in each row being stored with their points to the rear. The lowest tier in each row is to be placed on timber skids and similar skids are to be placed between successive tiers, it being intended that, if there are enough of them to require it, the projectiles may be stored as many as four tiers high.

Trolley tracks are attached to the ceilings of the shell rooms and pass above the centers of gravity of the projectiles in the two rows, and the trolleys running on these trolley tracks are to be used for carrying the projectiles to the shell tables.

As has been stated before, the most laborious part of ammunition service is in raising the projectiles up to a sufficient height to place them on the shell tables. To reduce this labor as much as possible, the idea has been introduced of raising the floors of the portions of the shell rooms utilized for storage purposes about 30 inches above the level of the floors of the galleries and of the shell rooms in the vicinity of the shell tables. This raising of the floors of the interior portions of the shell rooms places the second tier of projectiles as stored in the shell rooms at practically the same level as the projectiles that are on the shell tables. Consequently, in ammunition service, the projectiles which are stored on the fourth or on the third tiers have to be lowered in moving them to and placing them on the shell tables, and this lowering, of course, can be done practically without expenditure of energy. When the projectiles of the second tier have to be moved to the shell table all that is necessary is to raise them up just sufficiently to clear the skids and they can then be carried horizontally to the tables. The only projectiles, therefore, which have to be really raised in moving them from their storage places to the shell tables are those of the lowest tier, and these have to be raised only by an amount equal to slightly more than their own diameter.

The system of trolley tracks proposed for this new type of mortar battery is shown on Plate XXIX and, as will be noted, the idea of laying out the trolley tracks in loops has been carefully carried out, one loop of the trolley track passing over the two rows of projectiles and the two shell tables pertaining to each shell room. Additional trolley tracks are shown connecting these various loops in such a manner as to make it easily possible, by means of a trolley, to move a projectile from any part of any shell room to any part of any other shell room of the battery. In addition, trolley tracks are shown as extending through each of the galleries, connected at the front ends of the gallery with the trolley tracks of the two contiguous shell rooms, while at the rear ends of the galleries they pass over the ammunition supply railroad track.

The raising of the floors of the storage portions of the shell rooms, of course, requires that the ceilings be raised also, and since the trolley rails have to be extended from the shell rooms through the galleries, this means that the ceilings of the galleries have to be high as well. The plans show them about 11 feet above the floors of the galleries. This has the advantage, however, of permitting the trolley rails to be extended to the rear horizontally across the railroad track which passes in rear of the pits and permits, in ammunition supply, the projectiles to be picked up by trolleys directly out of the railroad cars in which they are brought to the battery.

The drawings on the plate show a railroad track in rear of the pits and also a switch leading out from this track to the rear. This switch is supposed to be connected with the main railroad system of the post, so that projectiles and other supplies can be brought by rail all the way to the battery. If there is no such post railroad system and ammunition supply has to be by wagon or truck, there should be constructed in rear of the pits, a paved roadway instead of the railway. The trucks or wagons with the projectiles can, in this case, be driven under the trolley rails.

It will be noted that in rear of the central traverse of each tactical mortar battery, that is, each battery of four mortars or half of the eight shown on the plate, there is shown what is known as a "plotting house." This plotting house is one of the special new features of this type of battery and came about as a result of the evolution of the design of plotting rooms for mortar batteries which will be discussed in the chapter on fire control.

The floor of the plotting house is on the same level as the floor of the pits. Each plotting house consists of one large room, about 16 by 32 feet, or about twice the size of the standard plotting room. Consequently, there is space enough in the main room of this plotting house for two complete plotting boards with their respective auxiliary apparatus and personnel. If all four mortars of a tactical battery are to be fired at the same target, only one of these plotting boards needs to be used at a time, but if it is desired to fire each half of the mortar battery, that is, each pair of mortars, at a different target, both the plotting boards are needed, using different fire-control data, and each working out special aiming data for its own two mortars.

In front, this main large room of the plotting house is extended to both flanks in the form of alcoves, in which is to be operated the mechanical indicating apparatus which displays the aiming data to the men in the pit by means of figures showing through slots in a small turret over the alcove. This mechanical indicating apparatus will be described more at length in the chapter on fire control.

The roof of the plotting house is intended to be used as a station for the officer in immediate command of operations at the battery. This roof is surrounded by hand railings and is reached by convenient stairways, one on either side of the plotting house. In order that the officer and others may be protected to some extent from the sun or rain, pipe awning frames are provided over which a removable canvas cover can be stretched.

An officer on the roof of the plotting house is placed in such a position that he can see everything that is going on in the two pits of his battery, and by means of a megaphone can give instructions to the men in the pits. By voice tubes he can communicate with the men in the plotting room beneath him. He has speaking-tube communication (not shown on drawings) with his powder and shell rooms, with the other plotting house, and with both battery commander stations. By walking to the proper places at the front corners of his roof, he can observe exactly what data is displayed by the indicating apparatus to the men in the pits. By crossing the bridge in front of the plotting house he can proceed to the roof of the traverse and thence, by convenient stairs, either up to the top of the parapet in front or downward into the pit.

The drawings show two battery commander stations located one on the top of each flank of the battery. The stations shown are of the standard size, 15 feet by 15 feet, and are of the two-level type.

The earliest batteries of this type were all designed for construction in ravines from which a view of the field of fire was not possible and no battery commander stations were shown on the drawings. Later, however, it was considered desirable to insert such stations on the general typical plans from which the drawings on Plate XXIX were made, and, as by this time the two-level battery commander station had become standard, the stations are shown as of that type.

Where mortar batteries have been actually built in ravines, as was the case in nearly all of the mortar batteries at Panama and in all of those recently built on the Pacific coast, battery commanders' stations at the batteries would have been useless and were, therefore, omitted. In such cases, other stations located at sites affording a good view were provided for the battery commanders' use and good telephone communications were provided between these stations and the batteries.

In designing this type of mortar battery it was expected that, wherever possible, mortar batteries would be located in ravines or behind hills, being thus hidden from the sight of the enemy and receiving from the hills a considerable amount of protection from the enemy's fire. However, it was known that in some cases it might be necessary to build the battery in the open, where it would be exposed to fire. In such cases it is, of course, necessary that the magazines be thoroughly protected. The drawings show such a battery, the magazines being given the same amount of protection as the magazines of the 1912 type of direct-fire battery; that is, the equivalent of 35 feet of concrete or 105 feet of sand.

Most of the mortar batteries built according to these plans have been located in the Tropics or in localities in the United States where trouble from condensation has not been experienced, and special arrangements for preventing condensation were not necessary. The typical plans, however, from which the drawings on the plates were made, are intended for use in places where condensation troubles have been experienced. They therefore show an air passage extending completely around the front of the entire battery from the power room on one flank to an outlet on the other. Arrangements are to be made by which the hot air blast from the radiators of the generating sets in the power room may, when desired, be turned through this air passage so as to warm up the thin wall between the air passage and the powder magazines. By properly regulating the solid doors in the openings between this air passage and the front of the galleries, warm air can be taken into any portion of the battery as desired.

The designs shown on the general plans, from which the drawings on Plate XXIX were taken, were intended for general use. Consequently, the rear ends of the flanks of the battery were purposely shown as unfinished, the method of finishing these ends and the question as to whether or not a parados should be provided being left to the constructing officer, as details directly dependent upon the conditions at each site. Several of the rooms in the left flank traverse are marked as intended for special purposes, such as the power room, the latrine, storerooms, etc. The rooms on the right flank are not specially assigned, nor are any rooms set aside for the special use of officers. All these matters also were left to the designing officer, who was expected to arrange one of these rooms for the special use of officers and to provide with it a conveniently located toilet.

Special ventilation shafts, not shown in the drawing, have usually been provided over the walls between the shell rooms and the powder magazines. In these shafts, suction fans have been installed for drawing the air out from the shell rooms and the powder magazines and thus ventilating them. The arrangements for this ventilation, for electric conduits, for electric lighting, for speaking tubes, and many other details are not shown on the outline drawings. Officers desiring information on the subject should obtain access to the drawings of the batteries of this type actually constructed.

The 1912 type of mortar battery just described is the present accepted standard, having been used in all 14-inch mortar batteries recently designed and, with the necessary changes in dimensions, for all 16-inch mortar batteries likewise.

One of the mortar batteries recently erected on the Pacific coast has some novel features which may be well worth mentioning. The battery is built in a ravine up which it was necessary to maintain a previously existing roadway. The battery consists of four mortars; that is, two in each of the two pits, but the relation between the normal direction of fire and the axis of the ravine is such that instead of placing the pits side by side, as is usual, it was necessary to place them one behind the other. Owing to the slope of the bottom of the ravine, the pits had to be built with their floors on different elevations. The ravine is so narrow that the battery extends completely across it, and the roadway which it is necessary to maintain is therefore located on a ramp, built in tunnels, passing up through the battery, and so connected with the different pits that it can be used for ammunition supply and for moving in the mortars and carriages.

CONSTRUCTION DETAILS.

In matters affecting the kind of cement used, the manner of mixing and placing the concrete, the prevention of dampness, the shape and size of the rooms, the method of roof construction, and in many other details, the development of the mortar battery went on in exactly the same way as was the case with the direct-fire emplacement. This has been noted in other chapters. However, there are some details of mortar-battery construction which appear to deserve special comment.

Size of Parapet.

If the sections of parapets shown in the early typical drawings of mortar batteries be compared with the sections of parapets shown on the drawings of direct-fire emplacements of about the same date, it will be noticed that the amount of protection provided for mortar batteries is much greater than that given the magazines of direct-fire batteries. I must confess that I have never been able to see the reason for this, for the mortar batteries are no more liable to be made targets by the enemy and are no more essential to the defense than the direct-fire batteries. In fact, it seems to me that, compared with direct-fire batteries of the same time, in some of the earlier mortar batteries the parapets were made needlessly large.

Locations.

From a study of the plans of the earlier mortar batteries actually built, it would appear that frequently as much advantage as was possible was not taken of the accidents of the ground providing both concealment and, to a considerable extent, protection. A battery intended for direct fire must, of course, be so placed that nothing intervenes between the battery and its target, but a mortar battery, which uses high angle fire and indirect aiming only, can well be placed behind hills or other natural obstacles.

With a direct-fire gun, the closer it is to the target the greater the effect of its projectiles, and, consequently, direct-fire batteries should in general be pushed as far to the front as possible. With mortar fire, however, the farther away the target is the higher in general the projectile must go to reach the target and the greater will be the velocity of fall and the penetration. Within limits, therefore, the farther away a mortar is the more efficient is its fire, while, on the other hand, there is for each type of mortar an inferior limit within which its fire is not effective.

For these reasons, it follows that mortar batteries can, in general, be withdrawn to the rear, and since they must necessarily use indirect methods of aiming there is no reason why they can not be placed behind hills, sand dunes, woods, or in rear of existing buildings. If some such fairly protected location be available, the mortars themselves need be given no additional protection and the only extra protection it is necessary to provide is a comparatively light cover for the magazines.

Unfortunately, on our Atlantic coast the conditions at the sites have been such that it has been almost impossible to ever find protected locations for mortar batteries, but on the Pacific coast and in the Tropics mortar batteries have frequently been placed behind hills or in ravines.

System of Zones.

The old smooth-bore mortars were usually fired at an elevation of exactly 45°, this being done because errors of elevation at this angle have less effect upon the range than at any other angle of elevation. Since the angle of elevation of the mortars was fixed, changes in range were obtained by varying the size of the charge of powder. Tables were kept in the powder magazines and, as soon as the range was known or was guessed at, the proper charge of powder was weighed out. This made it necessary, of course, to weigh out each charge of powder, which, if done accurately, required time.

With the rapid fire required under modern conditions there is no time to weigh out the charges. Furthermore, modern smokeless powder must be kept, almost up to the very instant of discharge, in hermetically sealed packages. Consequently it is necessary to prepare in advance charges of several different weights. It is possible to have only a limited number of different sizes of charge in storage, so the custom arose of making the main change in range by using charges of these different sizes and obtaining further variations in the range by changing the elevation at which the mortar is fired from 45° up to about 60°. As the elevation is changed within the limits mentioned, any one particular weight of charge will cover the distance between certain ranges, and as the mortar is rotated in azimuth each charge will cover a comparatively wide annular belt or zone. Each weight of charge has, of course, its own zone, but in order to leave some leeway when the change from one charge to the other is made, it is desirable that these zones should overlap slightly.

The inferior limit of mortar fire is, of course, fixed by the range resulting when the smallest charge is fired at 60° elevation. As the angle of elevation of the mortar is reduced from 60° to 45°, the range is increased and the outer limit of zone No. 1 is fixed by the range obtained when the smallest charge is fired at 45° elevation. The size of the next charge is necessarily fixed as that which, when fired at 60° elevation, will give a slightly shorter range than the smallest charge fired at 45°. The outer limit of zone No. 2 is, of course, fixed by the range given by the second charge at 45° elevation, and so on.

It is, of course, essential that exactly the proper charge of powder be used each time, because the elevation given to the mortar is based primarily upon the size of the charge of powder. The mortars are usually fired as rapidly as possible, and consequently, when the time comes for the charge to be taken to the gun it must be picked up hastily in the magazine and carried rapidly to the mortar. In haste of this character it would appear that mistakes might be made unless great care is exercised.

In order to render it almost impossible for such mistakes to be made the stall system of storage has been adopted. In this system each powder magazine is divided by light webbed-wire partitions into stalls. Each stall is to contain all the charges of one weight and none of any other weight. Information as to the particular charge to be used is given by the illumination of a red electric lamp over the entrance to the particular stall containing the proper charge of powder. This lamp is wired in series with a bell. At the proper time one of the detachment in the plotting room or in the mortar booth inserts a plug in a particular hole and this simultaneously strikes a single stroke on a gong placed in the magazine and illuminates a red lamp over the door of the stall containing charges of the desired weight. All that the powder man has to remember is that when the bell rings he is to pick up a charge of powder from under the red lamp and carry it to the gun.

In order to insure that the red light in the magazine will always be shining when the plug is inserted in the plug board, it is customary to place the lamp over the stall in series with the lamp over the plug board. If then the lamp over the plug board is shining, the man at the board knows that the red lamp is shining over the stall corresponding to the hole in which the plug has been inserted.

As the bell rings only once, that is, when the plug is inserted in a hole in the plug board, it is necessary to move the plug only when the charge is to be carried to the gun. If the same charge is to be repeated, the plug is removed an instant and is then reinserted in the same hole.

A zone system of signals, based upon the above principles, was designed by the writer and was installed at the mortar battery at Fort Monroe for test by the Coast Artillery Board. It worked so well that it was afterwards adopted bodily and a description of it was published as a Signal Corps fire-control mimeograph.

CHAPTER IX.

DRYNESS, HEATING, AND VENTILATION.

DRYNESS.

It might appear that the subjects to be jointly considered in this chapter are sufficiently distinct and are sufficiently important to justify being treated in separate chapters. It has been found, however, that one of the most difficult things to prevent, in attempting to keep magazines dry, is the condensation of moisture carried into the emplacements as watery vapor in the air. Further, it has been shown that condensation can be much reduced by proper ventilation and by the application of artificial heat. It is, therefore, convenient to combine the treatment of these three subjects in a single chapter.

Damage Done by Moisture.

The presence of water or moisture in the rooms, galleries, or magazines of emplacements is always to be avoided if possible. Formerly it was objectionable principally on account of its effect on powder. More recently, however, it is to be avoided rather on account of the damage it may do to machinery and of its effect on electrical installations.

Until the comparatively recent past about the only class of powder used in seacoast defenses was the so-called black powder. Not only could wet powder not be ignited, but since black powder was a mechanical mixture of certain ingredients and some of these ingredients were soluble in water, exposure to moisture was almost certain to injure the powder. Even if the powder was thoroughly dried thereafter, it would usually be found that its strength had been impaired, and the extent to which this impairment had gone was irregular and usually indeterminable.

In those days, for transportation and storage, powder was usually packed in barrels which were made as nearly water-tight as possible. It was, however, occasionally necessary to open powder barrels and unless extreme care was taken in refastening those barrels that had been opened, the powder was subject to injury, some of its ingredients being hygroscopic and having a tendency to absorb moisture from the air, especially when the atmosphere was nearly or completely saturated. For the above reasons, great care was necessary in keeping these older powder magazines dry.

The powder now used is a chemical combination rather than a mechanical mixture. Usually the powder contains volatile ingredients, and for this reason it is considered essential that it be transported and be stored in hermetically sealed cases. Into the cases moisture can not penetrate. Consequently, in so far as the effect upon the powder is concerned, the presence of moisture in magazines is less objectionable than it formerly was.

Existing emplacements, however, especially those built for larger guns, contain trolley tracks, trolleys, and hoists or other machinery. The iron or steel parts of all such machinery are subject to injury from rust, and although most of the exposed surfaces can be protected by being kept painted or covered with grease, yet it is almost impracticable to entirely protect those surfaces where wear takes place in actual use.

Electricity, also, is used in emplacements of all sizes, in connection with the lighting, power, and telephone systems. Moisture is a frequent source of electric leakage, grounds, and short circuits. In general, of course, electric leakage is so small that the loss is almost inappreciable in circuits receiving their power from dynamos and in occasional use only; but when the source of power is a storage battery, the slow and continuous leakage due to moisture has not infrequently been the cause of running down the battery and of considerable injury thereto.

By the use of properly insulated wires and cables, the leakage, in general, can be kept within reasonable bounds, but on switchboards and in electric switches and fixtures leakage is somewhat difficult to avoid if moisture be present. Grounding and short circuits must, of course, be avoided, especially in magazines or in galleries where powder is handled, for it is possible that a spark, due to a short circuit, might ignite the powder.

Another serious source of damage due indirectly to the presence of moisture is the damage to the insulation of electric cable caused by seep water. It has been found that water seeping through masses of concrete dissolves and carries with it certain elements which are very injurious to the lead coverings and even to the rubber insulation. Care must, therefore, be taken to prevent seep water from falling on or passing over wires and cables.

Although, as stated, the effect of moisture upon powder is no longer to be feared, yet on account of the effects of moisture upon the electric and mechanical systems, it is fully as important now as it ever has been to keep moisture out of emplacements.

Sources of Moisture.

Water may get into the galleries and magazines of emplacements in several ways.

(*a*) It may come in through the drainage systems designed to carry water away, either by the clogging of the system or by the backing up of water due to storms and tides.

(*b*) It may come in by seepage of ground water through the walls or floors of emplacements where such emplacements have been built in excavation below the level of the ground.

(*c*) It may come in in the form of rain or melted snow, absorbed in the surface of the concrete from above and working its way by seepage through the mass.

(*d*) It may come in the form of moisture carried in the atmosphere and deposited by condensation on the ceilings, walls, or floors, or upon articles stored in the emplacement.

Since the methods for preventing the entrance of moisture differ to a considerable extent according to its source, each of these sources of dampness will be treated separately. Furthermore, the treatment will, in general, be divided according to the means which should be applied in new emplacement construction, and to such means as may be available for stopping the trouble in old and existing emplacements in the original construction of which proper precautions were not taken.

Drainage.

Rain, of course, falls upon the roofs of batteries and upon other exposed places such as the loading platforms, sidewalks, etc. Snow, likewise, falls on such surfaces and eventually melts. Furthermore, it is not infrequently necessary to cleanse off the floors of the platforms and sometimes of the interior rooms, either by rinsing them with water carried in buckets or by turning the hose on them.

It is evidently desirable that water, whatever may have been its origin, should not be allowed to stand on the floors. Consequently, drainage slopes are always provided in the granolithic floor finish, not only of out-door platforms and sidewalks but also in the floors of interior rooms, magazines, galleries, and corridors.

The steepness of this drainage slope should, of course, depend upon the circumstances of the particular case; upon the area to be drained and the amount of water which may be expected. The slope should in all cases be as great as may be necessary for easy drainage, but frequently considerations other than those connected with drainage put a limit to these slopes.

Especially is this true where projectiles and other material have to be trucked over floors of galleries or platforms. In such cases it is desirable for easy trucking that these surfaces be made as nearly level as possible and that the drainage slope be reduced to a minimum.

On large surfaces and on sidewalks a slope as great as one-half inch to the foot is used quite frequently, but this is about as steep as is ever required for drainage purposes only, and where steeper slopes have been used in emplacement construction it has been not to aid drainage but in order to overcome differences of level between the floors at two parts of the emplacement.

Of course, in the interior of magazines the direction of the drainage is usually toward the outlet. Thus the floors of rooms usually slope toward the doors. In small rooms this slope is, for convenience, made in a single plane, except in cases where the door is located in the middle of one wall and occupies but a small percentage of this side of the room; here the floors near the door are sloped toward the door, and flat valleys sometimes occur at the junction between the different planes. In the larger rooms the drainage slopes are somewhat more complex. Usually they are such as to cast the water from the center of the floor toward the walls. Sometimes the floors slope two ways, with a ridge down the middle, and sometimes even toward the four sides. Occasionally, however, the floors are made to slope toward the center line, which is finished as a sort of flat valley.

The floors of galleries, corridors, passageways, etc., are usually sloped to a gutter at one side. Frequently they are made to slope both ways to gutters on both sides, and occasionally the slope is lengthwise of the corridor or gallery, with no gutter on either side.

Loading platforms, as a general rule, are made to slope outward, the highest portions in small barbette emplacements being at the base ring, and, in the larger emplacements, at the top of the steps leading down to the gun well.

The sidewalks in the rear of batteries, as a rule, slope to the rear and are finished with curbs and gutters such as are found in city streets.

Gutters.

Occasionally, as in the loading platform of the typical 6-inch disappearing battery (Plate XI), the drainage slopes are made continuous to the edge of the platform and the water is allowed to run down over the edge. Usually, however, the water cast off by the drainage slopes of floors and platforms is collected in gutters along the edges; that is, along the walls of rooms and galleries, the side walls of loading platforms, and along the rear of the loading platforms. (Plate XXII.)

These gutters vary in size from 2 or 3 inches in width and 1 inch in depth, the usual size of gutters around the walls of rooms, up to a width of from 4 to 6 inches and a depth of 3 inches for gutters which carry more water. In special places, where an accumulation of water occurs, the gutters are made much larger so as to be almost like city gutters. In some localities subjected to tropical rains drains as large as a foot or more in width and a foot or so in depth have been found to be necessary.

Drainage slopes are, of course, necessary in the bottoms of gutters. Such slopes usually vary from one-quarter inch to a foot up to one-half inch or more to a foot.

The design of the gutter system should, of course, be given careful consideration. The gutters should be placed so as to interfere as little as possible with the movements of the personnel. This requires that in rooms and galleries they be placed very close to the walls, and, where they pass in front of doorways, that door sills be built across the gutter, the water being passed through by pipes built through or under the door sill. In such cases, of course, arrangements should be carefully made so that water does not accumulate where the gutter enters or leaves the pipe through the sill.

In a few cases where gutters of considerable size have to run for considerable distances under walks which are in frequent use, iron gratings over such gutters are essential so that they may periodically be cleaned out.

Sumps.

As a rule the gutters are so designed as to carry the drainage to sumps, whence the water is carried away by pipes which extend either vertically downward or nearly horizontally under the floors. In the smaller batteries there are, as a rule, no sumps within the emplacement proper, but in the larger ones minor sumps within the limits of the emplacement are not infrequent. These interior sumps must, of course, be drained either into the larger gutters at the rear of the emplacements or to larger sumps outside. To prevent, or at least delay, the clogging up of sumps and of the drain pipe leading from them, it is well to have the sumps built fairly deep, with the bottom of the sump several inches below the bottom of the outlet pipe. This allows quite a little space at the bottom of the sump in which sand can accumulate, and if these sumps are cleaned out with sufficient frequency, the sand and débris can never rise up to the level of the outgoing drain and thus clog the drain pipes. (See detail on sheet 6, mimeograph 109.)

Of course, sumps so constructed will frequently have water standing in them, and to prevent these little pools from becoming breeding places for mosquitoes the sumps should be covered, below the regular grating, by a sheet of copper mosquito screen.

The drainage from the interior sumps in one-story emplacements, or from the sumps in the lower story of two-story emplacements, must usually be carried away by pipes laid under the floors, but from the upper story of two-story emplacements this drainage can very frequently be carried directly downward into the gutters on the lower story. For instance, the drainage from the sumps of the gutters on the sides and front of the loading platforms is frequently carried directly downward by means of pipes into the air spaces beneath, and thence by pipes along the walls of these air spaces into the gutters on the sides of the floors of these air spaces.

The portion of the drainage of the loading platform that goes to the rear is sometimes allowed to run completely to the rear of the emplacement and thence over the edge of the step, as has been noted in the platforms of the 6-inch emplacements (Plates IX, X, and XI, and mimeograph No. 59). In the larger two-story emplacements, however, it has been found that this rain water, running over the rear of the loading platform and falling down along the rear of the corridor of the lower story, is objectionable. It is now customary, therefore, to catch this drainage in a gutter built along the rear of the platform and to drain this gutter at proper intervals by pipes passing directly downward through the concrete to downspouts attached, as a rule, to the columns along the rear of the corridor.

Whatever arrangements may be made for the drainage of the sumps, care must be taken in all cases that these drain pipes be made fairly straight and that, wherever possible, the outlets be placed so that they can be reached. These outlets are, therefore, usually located either in the face of the curb of the walk in rear of the battery, or in the walls of the large sumps. It is also well to make these drain pipes larger than might be necessary merely for drainage purposes, in order that in case they should become clogged up in any way, it may be possible either to work a rod or wire through them, or even to wash them out with a small hose. When the drain pipes are very long, it is well to provide, at suitable intervals, hand holes or other arrangements for cleaning out the drains.

Drainage of Stairways.

Stairways, whether the treads be of concrete or iron, should also be given a drainage slope. In general, it is desirable that the treads never be made strictly horizontal but be given slight slopes so as to tend to keep the water running down the steps.

If the treads of steps be made strictly horizontal or slope the wrong way, rain water has a tendency to accumulate on them. This is not only disagreeable to people who have to use these steps, but in the winter and spring it tends to increase the accumulation of ice on these steps and, therefore, to make them unduly dangerous. A place where this difficulty is noticeably present is the steps of the State, War, and Navy Building in Washington. Whether this is due to faulty design, or to the fact that the building, and therefore the top of the steps, have settled more than the bottom of the steps, and have thus reversed the slopes of the treads, is not clear.

Drainage of Gun Wells.

In some of the older disappearing emplacements where the gun wells were small, it was not unusual to use these gun wells to some extent as intermediate sumps by turning into them an unnecessary amount of drainage. As the gun wells became larger and deeper, their bottoms were thrown down so low as to make their direct drainage difficult and steps were always taken to keep as much water as possible from getting into these wells. Thus the loading platforms were so built as to always slope away from the guns and thus divert the drainage of the loading platform away from rather than toward the gun wells. Water falling on the steps around the guns must, of course, be drained inward toward the gun wells and eventually passes downward over the curb of the loading platform level to the base ring level. This base ring level was frequently drained into the gun well itself and Ordnance Department platform sheets even now sometimes indicate this method of drainage. Generally, however, it is better not to do so, and in the larger and more recent emplacements an annular gutter has been built on the base ring level to catch all the water which may fall to this level. At convenient places around this gutter sumps have been provided from which pipes lead diagonally downward and outward, carrying this drainage water into the air spaces around the outside of the gun blocks and not into the gun wells. (See mimeograph 109, sheet 7.)

The gun wells in the 14-inch and 16-inch disappearing emplacements of recent design are so deep, and the sites selected for the batteries have frequently been so low, that in several cases the bottoms of the gun wells have been placed well below sea level. Natural positive drainage for such gun wells is, therefore, impossible, and it has been necessary to provide pumps for this purpose. With care in constructing the gun blocks the seepage of ground water into these gun wells should be avoided, but rain falling actually on the gun and carriage and water used for washing the gun and carriage, of course fall into the gun well. In the floor of the gun well, therefore, a sump has been provided in which this water accumulates. Along the route of the passageway leading into the gun well, a little pump room has been built and, by means of pumps placed in these pump rooms, the removal of the water is easy and simple. In general, as has been stated, the water to be removed is rain water only and the quantity usually is not so great as to prevent it from easily being removed by hand pumps. Power pumps, therefore, are not considered necessary for this purpose. (See Plate XXV.)

General Drainage.

The general principles of the drainage of emplacements, and for that matter, of other fortification structures, have been laid down above. The matter is extremely simple in its principles, and in small structures it is simple in practice, but in the larger and more complicated types of emplacements, the whole subject of drainage and especially the fixing of the slopes of the floor is not as simple as at first sight it might appear. The floor levels in many places are frequently kept within close limits by considerations not connected with the drainage system. Thus the ceiling levels are frequently fixed by the heights of trolley rails, the ceiling clearance of the room by the character of the material to be stored in the magazine, and thus it is not possible to raise the floors of certain rooms to the levels necessary to make the drainage simple.

Frequently, also, reverse slopes are necessary in various galleries and corridors, all of which must be taken into consideration in the design of the drainage system.

For the ordinary student, it is not necessary to go into such details, but it is suggested that before the inexperienced officer undertakes to design the drainage slopes of emplacements, he should give careful study to the expedients already successfully adopted; examining carefully the mimeograph sheets showing the drainage sheets of typical batteries and the drawings of a few of the more complicated batteries where difficulties arose, such as the drainage systems of batteries Webb, Warren, and Mower, Panama Canal fortifications.

Drainage and Sewage to be Kept Apart.

In this connection one thing is of especial importance, and that is that the ordinary water draining from a battery must be kept entirely separate and distinct from the sewerage system, not only within but also without the battery.

Failures in Drainage Systems.

The seashore of the Atlantic and Gulf coasts of the United States, where many of the early emplacements were built, is generally very low, flat, and sandy. The sand is very porous, rain water seeps into it rapidly, and consequently, in many cases, the Engineer officers who designed these early emplacements thought that it was unnecessary to provide complicated drainage systems to carry away the water from batteries, and that all that it was necessary to do was to have the drain pipes extend from the sumps downward into the sand. This was almost always the character of drainage provided for the larger sumps in the rear of batteries, and sometimes even of the minor sumps in the interior of the emplacements. It was the usual method of draining gun wells, the bottoms of which were quite low.

For a time this system of drainage worked fairly well, but in almost all cases it was found eventually that these pipes down into the sand became clogged up, partly due to the carbonate deposited by seep water, and, to a much greater extent, to waste oil from the machinery and gun carriages. The result was that the sand below these sumps in time became almost impervious to water. To remedy this, attempts were made to break up the hardened sand by driving down bars, but this was a temporary expedient only. Eventually, in practically every case, positive drainage from these older sumps has had to be provided, sometimes at considerable expense, as it frequently required the cutting of long drainage openings through several feet of concrete.

Fortunately, the difficulties of keeping open such indirect drainage systems were noticed in the early days and all batteries built subsequently have been provided from their inception with positive drainage. In the future, therefore, the matter will probably be of interest merely historically and as something to be avoided.

Stoppages.

Sand, earth, fragments of waste, trash, etc., are apt to accumulate on the floors of the rooms and platforms of batteries. Periodically these are swept away by members of the detachment in charge of the battery, and unfortunately the gutters and especially the sumps have been found very convenient places into which to sweep this material. In fact, the writer has seen a battery mechanic using the end of his broom handle to jam into the end of a downspout, material which could not otherwise be packed therein. It is needless to say that the sumps and downspouts can easily be clogged up in this way.

Occasionally complaints have been made to Engineer district officers that certain drainage pipes of emplacements had become clogged up, and an intimation has been given that it was due to defect in design, when the facts were that the clogging had been due solely and entirely to the improper use of these drainage pipes and sumps as deposit places for sweepings. The fault, therefore, instead of being with the Engineer Department, has been the lack of discipline in the detachment.

The instructions issued for the care and maintenance of emplacements always should, and generally do, state clearly and distinctly that all sand, fragments of waste, and sweepings should be carefully gathered up and be removed by hand from the battery, and should, under no circumstances, be swept into gutters or sumps. These instructions should be rigidly enforced.

Reversals in Drainage Due to Settlement.

The heavy masses of concrete of the parapets and in front of magazines, of course, weigh more per square foot of horizontal area than the rear parts of emplacements where there are rooms and galleries. Where the foundations of batteries have not been above reproach, due probably to the existence of mud substrata under the sand, the inevitable settlement has gone on irregularly, the heavier front portions of the emplacements settling more than the rear portion. Of course, this difference in settlement has not been great, but it has in many cases been sufficient to overcome the slight drainage slopes of only one or two per cent originally given to the platforms and gutters. After the settlement of such batteries, the loading platforms, instead of shedding their drainage water to the rear, have had a tendency to throw it forward against the front walls of emplacements, whence it has in some cases been able to find its way into the rooms and the magazines below.

In such cases it has been necessary to hollow out gutters along the front edges of these loading platforms a few inches from the front walls and to carry these gutters sideways and thence backward along the side walls until the drainage water can be disposed of.

Storm Tides and Floods.

As a rule our seacoast emplacements have been built along the seashore and except in a few cases, such as the forts near the mouth of the Mississippi River, their drainage has been little interfered with by river floods.

However, along the exposed beaches of the South Atlantic and Gulf coasts, our fortifications are directly exposed to the very high tides accompanying storms and great damage has been done by such storms.

Perhaps the worst trouble of this kind has occurred in the defenses of Galveston, where the level of the water in the harbor during one or two of the very noticeable storms of the past few years, has risen to an elevation of fifteen feet or so above the mean low water level; that is, to several feet above the level considered proper for the magazine floors when the older batteries were designed. The magazines and galleries of the first floor have, therefore, been flooded to a level of 2 or 3 feet, partly by water backing up through the drainage system, but more generally by the high water which covered to a considerable depth the parade grounds in the rear of the battery.

It is, of course, highly desirable that the floors of rooms, galleries, and magazines of batteries built on the seashore should be above any possible reach of high storm tides, and sufficiently above any storm-tide level to admit the installation of a complete system of positive drainage for all parts of the batteries, except possibly the gun-wells. Where any doubt exists as to whether this has been done in the older batteries, it is well to raise the parade grounds around the battery completely above any possible level of storm tides, and if positive drainage has been provided, to place check-valves in these drains so that water can not flow backward through them.

If this be done, it ought to be possible to keep the batteries from being flooded even though the actual level of the floors may be below the level of the storm tides. Such storms are usually not of long duration, the seepage of water through the ground into the battery will be slow, and such water as does seep through or work back through the drainage system or accumulate in the battery due to the heavy rains which usually accompany such storms, can ordinarily be kept out by pumping or even by bailing.

In general, in our middle and South Atlantic and Gulf coasts, it would appear that 10 feet above high tide level should be sufficiently high for the magazine floors and in a number of places magazines have existed at lower levels than this for many years without any trouble being experienced. This question, however, is in all cases one to be decided by local conditions, and usually where fortifications are likely to be needed, there are records available to the designing engineer which should give some clear indications as to how high it is necessary to build the floors of batteries.

Ground Water.

In a few localities in New England and on the Pacific coast, batteries have been built where economic conditions or conditions connected with concealment have required that the magazines of batteries be built in excavation. In some cases these excavations have placed the floors of the magazines several feet below the natural surface of the ground and below the level where the ground water usually stands, at least at certain seasons of the year.

Where such conditions exist, care must always be taken, and always should have been taken, to see that means of escape for this ground water are provided. The outer surfaces of the side walls should be waterproofed and against them should be placed porous layers, either of tile or of broken stone. Along the bottom of the walls, porous tile pipes should be laid with slightly open joints embedded in a mass of broken stone. These tile pipes should lead to sumps outside of the battery and should be made of sufficient size to carry away ground water as fast as it can accumulate. These tile pipes, taken in connection with the waterproofing of the wall surface and the porous tiles against the walls, should prevent the accumulation of water against these side walls whence it might seep into the battery.

There have been cases in the older batteries where water has seeped up through or around the floors of the rooms. It was customary to build the walls of the room first, leaving the floor space bare. These floors were subsequently filled up by earth or gravel to bring them approximately to the proper level, and the granolithic floor was then put in place. In such cases, when the level of ground water rose up high enough, water has seeped up through the cracks between the floor and the walls. Such occurrences have been rare, but the possibility should be kept in mind in future battery construction, and sufficient arrangements for ground-water drainage should be made to prevent it.

Seepage.

Rain and snow fall upon the upper surface of an emplacement whether this surface be composed of earth or of concrete. This rain water and melted snow must, of course, be disposed of. In order to encourage the rapid running away of this water, drainage slopes are always provided, but frequently, for reasons not connected with drainage, it is necessary to make concrete surfaces very nearly flat. Water falling on such surfaces drains away slowly, and before this has happened some portions of it may be absorbed into the concrete mass, through the very fine cracks called "hair cracks" and through the larger settlement cracks. Water once entering concrete in this manner works its way downward and may eventually appear in the interior of a battery as seep water.

Not only is seep water in a battery objectionable from its wetness, but it has been found also that seeping water dissolves carbonates in its passage through the concrete, and after the water enters the interior of the battery and begins to evaporate, the carbonate is precipitated and becomes visible in the form of stains upon ceilings and walls and occasionally in the form of stalactites or stalagmites. Such deposits are objectionable on account of their appearance, and it has also been found that seep water is exceedingly destructive to the lead covering of electric cables, to some extent to the rubber insulation, and also occasionally to the felts and tars used in waterproofing.

The concrete of the earlier fortifications was made with Rosendale cement and was usually mixed very dry as was the custom in those days. Such concrete; therefore, was quite porous, and seepage through it was exceedingly plentiful. This trouble has, to a large extent, been corrected in the later batteries by the use of Portland cement only, and by improvements in the manner of mixing and placing the concrete. Settlement cracks have been lessened by greater care in preparing foundations, and by leaving "planes of weakness" at convenient places, so that the formation of cracks which appears to be inevitable will occur only at places where expected and where no harm will be done.

This entrance of seep water to the magazine can be controlled at three places:

(*a*) By stopping it at the exterior surface and preventing it from entering the concrete;

(*b*) By stopping it and diverting it away by means of an intermediate waterproofing layer;

(*c*) Or by stopping it and disposing of it as it tries to enter the rooms and galleries.

Exterior Waterproofing.

The method of preventing water from entering the upper and exterior surface of the concrete depends to a considerable extent upon whether or not this surface is to be exposed to the air or whether it is to be covered by a blanket of earth.

Where there is no blanket of earth, and the upper surface of the concrete is exposed to the atmosphere, the entrance of water can be prevented, or at least greatly reduced, by giving to the concrete a sufficient drainage slope; that is, by diverting the water away as rapidly as possible and before it has a chance to seep in.

The next very important step is to make this upper surface of the concrete as waterproof or as water resisting as possible.

It has been found that when the concrete surface is made quite rich in cement and is properly manipulated, it can be made practically waterproof at first. Unfortunately, concrete is a poor conductor of heat. Its surface, when exposed to the sun's heat and to the coolness of night, is subjected to considerable variations in temperature, with consequent expansions and contractions. The interior masses, being subjected to much smaller temperature changes, are subject to much smaller contractions and expansions, and, as a result, the larger linear changes in the dimensions of the surface layer have a tendency in time to cause hair cracks to form in this layer. Once formed, these hair cracks widen little by little, extend deeper and deeper into the concrete, and through capillary action tend to draw in seep water.

As an aid to reducing seep water, there was introduced some years ago, at the suggestion of Col. (now Maj. Gen.) W. L. Marshall, a layer of crossed steel bars (see mimeograph 109, sheets 2 and 4) placed a few inches below the exterior surface. It has been found that while these steel bars do not absolutely prevent hair cracks from forming, yet they are a great preventive to the enlargement and spreading of these hair cracks.

Many attempts have been made to keep water out of concrete by covering its surface with a waterproof layer. Tars, asphaltum, and felt have been used for the purpose. The efficacy of tars and asphaltum in waterproofing depends upon their plasticity; that is, their ability to expand and subsequently to contract under temperature changes without losing their consistency and cohesion, and while still retaining their waterproofing qualities. Unfortunately, it has been found by experience that this plasticity, although lasting for a considerable time, is not absolutely permanent. In time, either due to the evaporation of volatile elements or to internal chemical changes, this plasticity is lost to a considerable extent, and thereafter tars and asphalts have a tendency to crack up, to separate from the concrete beneath, and to scale off in small particles.

These changes take place most readily where the tar and asphaltum is exposed to the air and sun, and, consequently, where temperature changes are greatest. When protected from the sun and air by a blanket of earth, the changes go on much more slowly, and where layers of pine tar (as distinguished from coal tar) have been utilized, the plasticity and waterproofing qualities of the tar would appear to last almost indefinitely. Thus the writer has seen at Fort Monroe the uncovering of some brick casemates over 50 years old. They had been waterproofed with a thick layer of pine tar, over which was a layer of sand and earth sodded on the top. When the earth and sand were removed, the tar was found to be so plastic that finger prints could easily be made in it. Again, in the city of Washington, in the destruction of an old building some few years ago, a cellar was removed which extended well below the ground-water level and which, nevertheless, had always been perfectly dry and free from leakage. The waterproofing of this cellar consisted of thick brick walls waterproofed on the outside by a thick layer of pine tar, while under the floor was a layer of pine tar inserted between two courses of brick.

For waterproofing purposes, pine tar seems to retain its plasticity much longer and, therefore, to be preferable to coal tar. It was stated to the writer some years ago by a chemist that this was probably due to the comparative absence of sulphur in pine tar and its almost certain presence in coal tar, this sulphur eventually causing a chemical change in some of the other components of the tar which were necessary to insure this plasticity. However, pine tar is now almost unobtainable and coal tar will usually have to be used instead.

Many attempts have been made at various times to use asphaltum for the purpose but though in most cases this asphaltum has worked well for short times, it has never proved to be durable and it is believed that experience with it has been sufficient to prove its unsuitability for this purpose.

When concrete is to be covered by an earthen blanket, there is usually no difficulty in making it thoroughly waterproof. It is necessary merely to provide a proper drainage slope for the concrete, to cover it with a layer of tar, asphalt, or waterproofing felt, to provide outside of this a layer of porous tiles containing open passageways which will permit any water to rapidly drain away, and to provide sufficient drainage for this water when it has reached the foot of the wall. With such an arrangement, seep water will ordinarily not be able to enter the concrete. But should it be subsequently found that there was any defect in the waterproofing, or should any defect occur later and subsequent to the original construction, it is a comparatively simple matter to remove the earthen blanket to correct the defect and then to replace the earth.

In the chapter describing the general character of emplacements, it was stated that the most modern designs provide for the covering with earthen blankets of practically all of the concrete except the tops of retaining walls, blast aprons in front of the guns, loading platforms, and walks or passageways. Consequently, in such batteries, the waterproofing is much simplified over the older types where the concrete over the magazines and the traverses was exposed to the air in practically horizontal planes. About the only place where difficulty in waterproofing is to be expected now is in the rooms under the loading platform in the few cases where the two-story type of battery is to be built and such rooms are to be installed.

Attempts have been made many times to render exposed exterior surfaces of concrete waterproof by painting them with some waterproofing mixture. Linseed oil made more liquid by the addition of naphtha or gasoline has been tried but not with great success, especially since the linseed oil has occasionally a tendency to cause the disintegration of the concrete. Occasionally, special patent preparations have been used for this purpose with apparent success for a short time.

For the above reasons, it is thought by the writer to be better in future construction not to resort to any of these patent preparations but to rely for the water-tightness of the concrete upon a rich and carefully floated surface, upon a cross-layer of reinforcing bars a few inches below the surface to prevent the seepage cracks from growing, and to then install somewhere within the mass of the concrete an interior waterproof surface as will hereinafter be described.

The above remarks relate, of course, to new construction only, but frequently in the past the engineer has been confronted with the problem of stopping seepage water in older batteries and many different solutions have been attempted.

In a number of cases the seepage can be traced to a few very noticeable cracks on the surface, and the method of curing this has generally been to cut out the sides of the cracks until they are sufficiently large for the purpose, to thoroughly clean the new surfaces from dust and dirt, to paint these surfaces with tar applied hot, and then to fill the cracks with an elastic compound which will not flow in hot weather and will still retain its plasticity in cold weather. Tar as a rule has not been found to be durable for this purpose. Asphalt has proved a failure. Webster cement is said to last better.

In some cases an attempt has been made to cover an entire loading platform through which there was considerable seepage into the rooms below, with a regular asphalt covering. Usually this experiment has resulted in failure as it has been found that wherever the asphalt is made sufficiently plastic to remain uncracked in cold weather it becomes so soft in hot weather that the wheels of the heavy trucks sink into it and, consequently, the labor of moving the trucks is very much increased.

Intermediate Waterproof Surfaces.

The use of an intermediate waterproof surface to prevent seep water from entering the rooms, galleries, and magazines of emplacements is an invention of Maj. (now Maj. Gen.) W. L. Marshall, Corps of Engineers. The theory upon which its use is based is as follows:

Where concrete surfaces are exposed to great extremes of heat and cold and, therefore, to extremes of expansion and contraction, the formation of cracks appears unavoidable and these cracks, once formed, have a tendency in time to extend farther and farther into the concrete mass, at least as far as the concrete is monolithic.

Within the concrete mass temperature changes and, therefore, expansions and contractions, are much smaller than at the surface and take place so much more slowly that temperature cracks are not apt to form. If, therefore, within the mass of the concrete we can provide a waterproof surface, and can so separate it from the exterior concrete that cracks can not be transmitted to it, this interior surface should remain waterproof practically indefinitely.

Gen. Marshall therefore proposed to provide within the interior of the mass a properly drained waterproof surface and to separate it from the concrete above it by a layer of sand and fine gravel through which a crack could not be transmitted. That is, he proposed to make a waterproof surface and to provide it with proper drainage slopes leading to drains which would carry the water away where it can do no harm. When thoroughly hardened this waterproof surface was to be covered by a layer several inches thick of sand and of fine gravel through which, of course, the water could percolate and drain away. Above the sand and gravel he proposed to install a stratum of concrete made very lean in cement and mixed so dry that no cement water would leak from it to the sand and gravel below it. Above this dry layer of concrete he again started his regular concrete construction and continued it to the outer surface.

Being protected from sudden temperature changes this interior surface should remain uncracked indefinitely, and any water that might seep to it will be diverted away by it in the direction to which drainage is provided and pass off through the sand until the drain pipe is reached.

In construction, the concrete near this interior waterproof surface is made quite rich in cement, and the surface is very carefully treated and floated so as to be thoroughly waterproof. To prevent any hair cracks developing, as the surface hardens, and before construction work can be carried further, it must be carefully protected during the hardening process. As an aid to this it has been found desirable, especially in the tropics, to allow the hardening to take place under water. That is, the regular means of drainage is temporarily plugged up and as soon as the initial set of this surface has been obtained, water is allowed to flood slowly over the surface and to rise to a sufficient depth to cover it entirely. The concrete thus gets its final set and does its hardening under water. After some three or four weeks have elapsed, the water is allowed to run off and the surface to dry. While drying it must be exposed, of course, to the atmosphere, but must be kept thoroughly protected from the sun. After it has dried the surface is ready for the layer of sand, gravel, etc.

Gen. Marshall did not consider that the addition of tar or felt to this surface was necessary, but in most recent cases the constructing officers have painted the waterproof surface with tar and covered it with felt immediately after it had become thoroughly dry, thus providing an additional precaution.

Where an intermediate concrete surface is to be built in a battery, there is one possible source of trouble which should be kept in mind by the designing officer, and that is the tendency which has occasionally been shown for an over-lying mass of concrete, under the influence of continuous temperature changes, to move bodily but slowly over an underlying stratum, where the two are separated by a comparatively smooth and nearly horizontal joint. The separating stratum of sand, between the waterproof surface on the one hand, and the mass of concrete above it, could easily permit such a bodily movement. Such a movement might, therefore, be expected to take place in time if means are not taken in the beginning to prevent it.

Stopping Seep Water as it Tries to Enter Rooms or Galleries.

A problem of this kind should present itself in the future only in the case of the older batteries, for if an emplacement has been properly designed and constructed the entrance of seep water will have been prevented by one of the methods mentioned above or the seep water will be diverted by an intermediate waterproofing surface such as has just been described.

There are, however, a number of our older batteries where proper care was not taken at the time of construction, and where seep water enters the room and must be stopped or carried away as it does enter. Fortunately, however, all of these poorly designed and constructed earlier batteries have already or will shortly become obsolete.

The first and simplest method which suggests itself is, of course, to paint the wall surface with some water-repellent substance applied as an emulsion or as a paint. There are a number of widely advertised substances on the market for doing this. The method has been tried many times, and at first, in a number of cases, has appeared to work well. It has in fact worked well for an indefinite period in some few cases where the hydraulic pressure never became great. In general, however, when the seep water has been unable to enter the room on account of the substance applied to the wall, it has backed up in the cracks or paths through which it seeped until the hydraulic pressure has become so great that the water began again to make itself apparent at the same place as before, in spite of the water-repellent application, or showed itself in some other place, sometimes indeed in the form of an increased amount of seepage at the other place.

The next step was to catch and carry away the entering water by building what is practically an independent house in the old room or magazines. Many fairly successful methods of doing this will be found noted under the head "Technical details" in a number of older annual reports of the Chief of Engineers.

Sometimes these interior rooms have had their own independent walls separated from the original wall surfaces by air spaces, and sometimes they have consisted merely of a roof.

These interior walls have usually been constructed either of brick or timber; the roofs usually of timber covered by an impervious surface such as felt or sheet metal. Sometimes the roofs have been made of corrugated iron or copper without the timber.

All of these constructions, as long as they remained intact and in good condition, have been fairly successful in catching and diverting the seep water, and incidentally, by providing thin walls surrounded by air spaces, they have to a considerable extent reduced condensation. However, all these interior structures require space and reduce the dimensions originally given to the room. In the older batteries the rooms were barely large enough anyhow, and this reduction in their dimensions has been quite serious, especially as regards ceiling height or, as it may be called, "head room."

Moreover, wherever timber was used for this purpose, it decayed quite rapidly except where a very expensive quality of cedar was used. Frequently, too, the timber or fiber used, not long after the interior rooms were constructed, has become moldy, smelly, and in many other ways objectionable.

In one case a characteristic difficulty occurred in connection with an interior roof. This was in the mortar battery at Fort Monroe. This battery is one of the oldest of the seacoast batteries constructed. Rosendale cement was used in its construction and the concrete was exceedingly porous. Apparently the exterior surface of the concrete, where it was covered by sand, was imperfectly waterproofed, for before long large quantities of seep water appeared in the battery after nearly every heavy rain, forming stalactites and stalagmites in the rooms and galleries.

Fortunately, this battery has been built with considerable headroom, but the rooms were too narrow to permit any interior walls to be built. Consequently, the method of damp proofing was to construct an interior ceiling of corrugated copper, sloping from a central ridge to small gutters which were cut in the side walls. These gutters were drained at intervals through down spouts likewise cut into the side walls.

At first, and for a number of months, this interior roofing was quite successful, but finally, one by one, leaks began to appear at the joints where the corrugated sheets lapped and soon increased rapidly until they became very objectionable. Investigation showed that the cause of the trouble was that the gutters and the down spouts had become almost completely stopped up by the stalagmites deposited by the seep water. The seep water, being in this way prevented from passing out through the drainage system provided, backed up until it appeared through the joints in the roof. To remedy this trouble, it was necessary to remove portions of the roof and to clean out the stalagmites from the gutters and spouts. This done, the system again worked well, but the cleaning has had to be repeated periodically.

Condensation.

Of all the moisture in batteries that brought in by the atmosphere and deposited by condensation is the most difficult to combat.

The natural laws governing the carrying of watery vapor in suspension in the atmosphere and the subsequent condensation of this watery vapor, are really quite simple, yet they are quite frequently misunderstood and many of the remedies which have been suggested have been such as to do more harm than good.

Natural Laws Governing Evaporation and Condensation.

Air possesses the ability to pick up and carry in suspension within itself watery vapor in a gaseous form. The weight of watery vapor per cubic foot of air which can thus be carried depends on the temperature of the air and increases rapidly with an increase in temperature. This amount of vapor is shown in tables found in engineering handbooks, which may be examined if desired. In general, it may be stated that within the limits of ordinary atmospheric temperature, say, from 10° to 100° F., a rise of temperature of 10° increases by about 50 per cent the ability of the air to hold moisture in suspension, while a rise of temperature of about 35° practically triples the amount of moisture which the air can carry.

When the air contains within itself the maximum amount of watery vapor which, at its temperature, it is able to carry, it is said to be "saturated." When it contains less, it is not saturated. The degree of saturation is usually expressed in the form of a percentage, indicating the ratio between the actual amount of watery vapor present and the maximum amount of watery vapor which the air at that temperture can carry.

If a mass of air not fully saturated is brought in contact with or passes over a pool of water or a wet surface, the air has a tendency to pick up moisture from these sources, and this process will continue either until all of the water has been evaporated or until the air has become fully saturated.

If, on the other hand, for any reason whatsoever such as cooling, the amount of water carried by the air becomes greater than it is able to hold at its new temperature; or, as it is sometimes stated, the air becomes temporarily supersaturated, the watery vapor present in excess of that necessary for saturation will be given up by the air. This moisture ceases at once to exist in the form of vapor and is transformed into very minute drops of water. Where very numerous these minute drops become visible in the form of fogs or clouds. They have a tendency to slowly settle through the air and to be deposited in the form of dew or condensation upon any convenient object. When the cooling is due to the passage of the air over or along cooler surfaces, the deposit usually and naturally takes place on these surfaces.

Since the ability of the air to carry watery vapor in suspension varies rapidly with the temperature, the percentage of saturation may be changed by a change in the temperature of the air and without the addition or subtraction of any watery vapor. If the temperature be raised, the ability of the air to carry watery vapor increases; that is, the amount of water necessary for saturation increases and, consequently, the proportion which the amount of watery vapor actually present bears to that necessary for saturation is decreased and there is thus a decrease in the percentage of saturation. Consequently, if saturated air be heated, the percentage of saturation is reduced and, as thus heated, the air possesses the ability to take up and carry an additional quantity of moisture.

If, on the other hand, the temperature of the air falls, its ability to carry watery vapor is decreased, and the ratio that the amount of watery vapor actually present bears to that necessary for saturation; that is, the percentage of saturation, is therefore increased. If the cooling be continued far enough, the ratio between the amount of vapor present and that necessary for saturation will become unity, and any further cooling will be followed by the deposit of moisture or, as it is called, condensation. The temperature at which this occurs is called the dew point.

From the above statement of natural laws we can now lay down the fundamental rules to be used in designing means for reducing condensation in emplacements.

Anything which serves to raise or to keep up the temperature of the air, or of the surfaces with which the air is to come in contact, serves to increase the ability of the air to hold moisture in suspension, and, therefore, tends to reduce condensation.

Anything which acts to lower or to keep down the temperature of the air, or of the surfaces with which the air is to come in contact, serves to reduce the ability of the air to hold moisture in suspension and tends to increase condensation.

In other words, the prevention of condensation is largely a question of raising or keeping up the temperature of our emplacement walls.

Loss of Heat.

We learn in our study of heat that, in general, heat can be added to or taken away from objects in three ways, and in these ways only: *Radiation*, *conduction*, and *convection*.

Radiation.

The temperatures of the ceiling and of different portions of the wall surfaces of an emplacement are, under ordinary circumstances, so nearly the same that any heat lost by radiation from one surface or part of a surface is equalized by the radiation received from the other surfaces. Consequently in the interior of emplacements radiation as a source of warming or cooling may, for all practical purposes, be neglected.

Conduction.

When the wall surfaces are cooler than the mass of concrete, heat is conducted from the mass of concrete to the wall surfaces and the temperature of these surfaces is raised. When the temperature of the wall surface is above that of the mass of concrete, heat is conducted from the surface to the interior and the surface temperature is reduced.

The former of these two conditions—that is, when the temperature of the center of the mass is greater than that of the wall surface—occurs only during the fall and early winter months when the temperature of the concrete is greater than that of the air and there is no tendency to condensation. Consequently at such times it is immaterial, so far as condensation is concerned, whether the mass of the walls be a poor or a good conductor of heat.

On the other hand, in the spring and summer when condensation difficulties are greatest, the temperature of the air, and incidentally the temperature of the wall surfaces, is above that of the mass of the concrete, and there is a constant tendency to a loss of heat from the wall surfaces by conduction into the interior of the mass. To reduce condensation it is essential, according to the rules deduced above, that the temperature of the wall surfaces be kept up as much as possible, and consequently anything that tends to reduce the loss of heat by conduction tends to keep up the temperature of the wall surfaces and to reduce condensation. We may, therefore, state the rule:

Efforts should be made to reduce the heat conductivity of the interior walls, especially near the surfaces of the walls.

Convection.

The change of the temperature of the walls of an emplacement by convection goes on constantly, whenever there is a current of air passing through the battery. If the air be cooler than the battery walls, the temperature of the walls is lowered by the loss of heat absorbed by the air in its attempt to rise to the same temperature as the wall surfaces. If the air be warmer than the walls of the battery, then the walls are warmed by convection; that is, by heat given off by the air not only due to the cooling of the air but also in the form of latent heat due to condensation. This requires a discussion of the natural laws relating to the property called "latent heat."

Latent Heat.

If a mass of water be slowly heated its rise of temperature will be closely proportionate to the amount of heat added, and this will continue until the boiling point is reached. Thereafter the addition of heat will result in the change of water to the vaporous form of steam, and no rise in temperature will occur until all the water has been transformed into steam. In other words, the heat which is added after the water has reached the boiling point results, not in change of temperature, but in change of form. It has been found by experiment that the amount of the so-called latent heat necessary to transform any quantity of water into steam is very large, approximately 960 times the amount of heat necessary to raise the temperature of the same quantity of water 1° F.

In the cooling down the reverse process takes place. As heat is given off by steam its temperature slowly decreases until the boiling point is reached, then follows the condensation of the steam into water, and during this condensation all of the latent heat which was taken up in the process of boiling is given off.

When evaporation or condensation takes place at temperatures below the boiling point, there is the same phenomenon of the absorption and giving off of latent heat as at the boiling point, and the amount of latent heat per pound of water thus absorbed or given off does not differ very greatly from that absorbed or given off at the boiling point.

That is, in order that the evaporation of water may take place, the adddition to the water of the latent heat necessary for vaporization must take place, and this heat will be obtained by absorption from the temperature heat of the remainder of the water or of other substances with which the water is in contact. This is noticed in the cooling which usually accompanies evaporation.

On the other hand, whenever condensation takes place this condensation is accompanied by the giving off of latent heat, which thus becomes sensible and has a tendency to retard the cooling of the air containing the moisture and to warm up the objects upon which the moisture is condensing. Condensation of itself is, therefore, not an unmixed curse, because it is necessarily accompanied by the giving up by the watery vapor of the latent heat of vaporization. Every bit of heat thus given out raises the temperature of the wall turfaces and by just so much diminishes the amount of condensasion which will subsequently take place.

Although, as has been stated, moisture in emplacements is usually to be avoided, yet there are places where it is much more objectionable than at others. Near machinery and electric switchboards condensation is to be avoided, but in corridors and passageways it can ordinarily do but little damage, and in the air spaces of the most modern types of batteries condensation can do no harm at all, while the latent heat given off during the process of condensation is an advantage.

Therefore, in order to encourage the warming of the battery walls by convection, it is desirable to increase the circulation of air throughout the battery whenever the outside air is warmer than the interior wall surfaces, and to do this so that, if possible, condensation will take place, not at points where it is objectionable, but at places where it can do no special harm. To accomplish this our most modern batteries have been designed with 2-foot air passages around all the magazines and other principal rooms. (See Plates XVII, XX, and XXII.) They communicate directly with the outside air in the rear and, by means of stairways, corridors, and ventilators, with the front and side walls of the loading platforms. They are provided with two separate systems of doors, solid doors to cut off ventilation and grating doors which keep out intruders, while still permitting ventilation. A proper use of these solid doors requires that they be kept closed whenever the temperature of the outside air is below that of the wall surfaces inside, but that they be opened wide whenever the reverse is true. Ventilation around and through the battery is thus encouraged under conditions which will slowly warm the battery up, and the inevitable condensation takes place principally in the air spaces where it can do no harm and where it in reality does good by warming up the wall surfaces on which the condensed drops of water are deposited.

Wet and Dry Bulb Thermometers.

The fact that evaporation requires the addition of the latent heat of vaporization is made use of in an apparatus used to measure the dew point of the air, and therefore incidentally the degree of saturation. As this instrument is in common use in our coast defenses and as the theory of its use well illustrates one of the laws governing condensation and evaporation, it may be well to briefly describe it here.

This apparatus is known technically as the psychrometer, or in more ordinary language as the wet and dry bulb thermometer. It consists of two thermometers exactly alike mounted close together on a portable stand. The bulb of one of these thermometers is dry, the other is surrounded by a thin layer of cotton or wick, which leads from the bulb to a bottle or tube containing water, so that the cotton around the bulb is kept always moist. If the instrument be kept still, especially in saturated air, these two thermometers will read alike. When evaporation, however, is taking place the mercury in the wet bulb is cooled by the evaporation of the water from the cotton or wick and there is a difference in the reading of the two thermometers.

When it is desired to use this instrument for measuring the dew point it is taken to the place where the measurement is desired and is rapidly swung round and round in the air. The motion of the thermometer through the air causes evaporation from the cotton cloth covering the wet bulb, and this evaporation cools off the mercury in that bulb, the cooling process continuing as long as evaporation takes place. Theoretically, this evaporation will not cease until the temperature of the surface of the wet cloth, and, presumably, therefore, the temperature of the mercury in the wet bulb, has been lowered to that, which, with the amount of moisture actually present in the air, corresponds to a condition of saturation.

The wet bulb will indicate the dew point of the air and recourse to a table will show the amount of moisture present per cubic foot of air. The dry bulb will continue to give the actual temperature of the air, and the table will show the amount of moisture which the air at that temperature is able to hold. The ratio between the amount of moisture actually present and that which can be carried at the temperature gives the percentage of saturation.

Extent and Character of Temperature Changes in Emplacements.

Modern emplacements, as a rule, are composed of large masses of concrete, the walls and ceilings, for protective reasons, being made very thick. The outer surfaces of this concrete, such as the roofs, loading platforms, and the rear walls, are exposed to atmospheric agencies, and the temperatures of these surfaces do not, as a rule, vary greatly from the temperatures of the air. In summer, with the sun's rays beating down upon them, these surfaces become very warm and this heat is slowly conducted to the interior of the concrete mass. In winter, on the other hand, the exposed surfaces radiate their heat and by being covered with ice and snow or by being in contact with cold air they cool off to approximately the atmospheric temperature. This cooling, likewise, is slowly transmitted to the interior.

To determine, if possible, the character and extent of the temperature changes within the mass of concrete, some experiments were made at Fort Monroe during 1903 and 1904. A description of these experiments is not necessary, as only the results are important. These results showed that in general the temperature of the interior of a mass of concrete passes through a seasonal change, falling in the autumn and winter and rising in the spring and summer. The amplitude of the change, however, was shown to be only about half of the atmospheric changes of temperature, and, furthermore, the lowest temperature followed in time considerably after the coldest weather of the winter and the highest temperature occurred considerably after the greatest heat of the summer.

As a result of this lag in the temperature changes, it was evident that there were likely to be days in the spring or early summer when the temperature of the interior of the concrete mass might be 40° or so below that of the atmosphere; on the other hand, that there would be times in the early winter when a similar difference but in the reverse direction might be expected.

That the temperature changes in the interior of a mass of concrete would be less than those of the atmosphere, and that the extremes of the seasonal temperature changes would lag somewhat behind those of the atmosphere had, of course, been anticipated, but it was not expected that the differences in temperature and the lag would be as great as was indicated by the experiments.

The results obtained from these experiments, however, gave a clear explanation of the phenomenon already noticed, that the amount of condensation in batteries of similar construction but in different localities seemed to depend to a great extent upon the amplitude of the atmospheric temperature changes. That is, on the middle and north Atlantic coasts, where the difference between the winter and summer temperature is very great, condensation is extremely difficult to deal with. On the Pacific and Gulf coasts, where the general temperature changes are smaller, condensation is very much more easily prevented, while in the Tropics, where the seasonal temperature changes are extremely small, condensation is practically negligible.

Condensation in Emplacements.

Our seacoast fortifications are necessarily located on the seashore where, due to the influence of the ocean, the percentage of saturation is quite high. This is especially true during the spring and early summer when, for several hours nearly every day, the wind blows from the sea, bringing in air that is not only warm, but which is always nearly, if not entirely, saturated. Consequently, along our seacoasts in the summer time the dew point is usually only a few degrees lower than the atmospheric temperature.

When such warm, moisture-bearing air finds its way into an emplacement or battery and comes in contact with the cool ceiling and wall surfaces, condensation is to be expected.

At first sight it might appear that we could reduce the amount of condensation in one of three ways:

(1) By taking the moisture out of the air.

(2) By preventing warm air containing moisture from entering the battery.

(3) By reducing the tendency to condensation of the moisture which is in the air entering the battery.

The first method, to remove the moisture from the air, is evidently not practicable. The second method, to prevent moist air from entering a battery, is incompatible with the opening of the doors and windows which is necessary when the battery is in use. Consequently, we can rely on the third method only, which is to reduce the tendency to condensation of the moisture which actually finds its way into the battery. This, as has been stated in the rules above, can be done only by increasing or keeping up the temperature of the emplacement walls.

If into a room the walls of which are cold, there be introduced a quantity of warm, moist air, there will, of course, be a deposit of moisture and this deposit will be greatest near the doors or windows where the air first comes in contact with the cool walls. As the air cools off condensation will take place, but the heat lost by the air in cooling, as well as the latent heat given off by condensation, will be absorbed by the walls. Consequently, as the air cools off the walls warm up, and this process—the cooling of the air and the warming of the walls—will continue until the walls and the air are practically of the same temperature. The condensation will continue until the amount of vapor still remaining in suspension is just that necessary to produce saturation at the temperature to which the air has now fallen. After this condition has been reached, the cooling of the air and the condensation of moisture will go on much less rapidly and only as the heat is conducted from the walls into the interior of the mass of concrete. This is a process that is far from rapid.

If the rooms of a battery, which have been kept closed all winter and are at a temperature far below that of the outside air, be opened in the early summer time, the warm, moist air rushes in and the inside air rushes out until there has been one complete interchange of air. Condensation will take place, but the amount of moisture, though considerable, will not be excessive and will be limited to the difference between the amount of moisture the air contained when it entered and the amount which it can contain in suspension when reduced to the temperature of the magazine walls.

If instead of this single interchange of air, however, we have conditions such that there is a fairly rapid circulation of air through the battery, entering at one point and leaving at another, each portion of the air as it passes through will deposit its own quota of moisture and the total amount of moisture deposited may be considerable. However, as this warm air passes through the battery it transmits to the walls temperature heat as the air cools off and latent heat as moisture condenses. It thus gradually warms up the walls. If the circulation of air be sufficiently rapid, the surface of the walls will, before long, be raised to approximately the temperature of the air, or if the air be not completely saturated, to the dew point. After this, provided there is no increase in the amount of moisture carried in the air, no further condensation can take place except that due to the slow loss of heat by conduction from the wall surface into the interior. In other words, the passage of warm air through a battery has a tendency to heat it up, even though this heating be accompanied by condensation, and eventually, if the circulation be rapid enough, the condensation will cease.

If, however, as sometimes occurs, the passage of the moist air through the battery or portion of a battery takes place quite slowly, so that heat is transmitted from the air to the walls only at the same speed as it is lost by conduction from the wall surface into the interior, we have the worst possible condition, as condensation may go on indefinitely.

When, therefore, a circulation of moisture-bearing air is permitted through a battery, this circulation should be made to take place as rapidly as possible.

Means Taken to Prevent Condensation.

It would appear well at this stage of the discussion to give a short historical rèsumè of the means which have actually been taken to prevent or reduce condensation in batteries.

When fortification construction was resumed in the early nineties and the earlier batteries, emplacements, and casemates were designed, the idea of condensations being objectionable seems never to have occurred to the designers. No means for preventing this condensation were provided and, with the designs adopted, condensation was inevitable. However, it was not long after these emplacements were completed before it was found that the magazines and galleries were disagreeably wet, and it thus became evident that some provisions to reduce condensation must be included in the designs of all emplacements to be built thereafter.

At first the methods of preventing, or at least of reducing, condensation were left to the constructing officer, but before long they began to appear in the mimeograph designs. The first method shown in the mimeographs was based upon the maxim stated above, that of reducing the heat conductivity of the wall surface. This was done by inserting small air spaces 5 or 6 inches wide in the walls around the magazines and shell rooms. (See Plates VIII, XIV to XVI, XVIII, and XIX.)

Unfortunately, the idea of water seeping into these air spaces does not seem to have occurred to the builders and, consequently, many of them were made blind—that is, no provisions were made for their drainage. The concrete, at the time, was made of Rosendale cement. It was usually mixed quite dry and was, therefore, very porous so that water could seep through it easily. This water frequently found its way into the air spaces, and once inside would run rapidly to the floors of the spaces, whence it would try to seep away. Unfortunately, the seep water usually contained carbonates in solution and these carbonates had a tendency to make deposits upon the floors of the air spaces which made them less permeable and thus seriously interfered with the seepage of water away from them. Consequently, the water would seep in faster than it would seep out and often the spaces became filled. From the air spaces it was but natural for the water to seep through the thin walls into the magazines and galleries and it thus became a source of trouble. To avoid this, it became necessary in many cases to drive drainage holes into these air spaces so that they would readily empty.

The next step was the introduction of the 2-foot air passages first shown in the drawings of the 1903 type of 10 and 12 inch emplacements. (See Plates XVII and XX.) These air passages are just outside of the magazines and principal rooms of the batteries. The walls separating the passages and the rooms or magazines are thin and the loss of heat by conduction from the surface of magazine walls can, therefore, not be great. Furthermore, the circulation of air through the air spaces and the condensation of moisture therein warm up the walls of the magazines. These air spaces thus tend to reduce condensation in two ways; first by reducing the conduction of heat away from the wall surfaces of the magazines and storerooms, and second, by warming up these wall surfaces from the outside.

To act efficiently in the manner mentioned, it is evident that the circulation of air must be rapid. As first designed, the air spaces had apparently an unnecssary number of sharp turns. It is a well-known fact that every angle in a ventilating passage impedes the motion of air and, consequently, to encourage a rapid motion of the air the number of angles should be made as small as possible.

Although these air spaces opened on the rear face of the battery, their connections with the front and side walls of the loading platform were not sufficient and there was but little to induce the circulation of air through them.

These deficiences were noted and were, to a great extent, corrected in the design of the 14-inch emplacement shown in mimeograph 109. (Plate XXII.) In the designs shown in the mimeograph, the air spaces under the loading platform and around the gun block are built in gentle curves instead of sharp angles. Frequent openings are provided to the long gallery extending from one side of the battery to the other in front of the magazine space. Communications are also provided leading up to the loading platforms and, in addition, numerous ventilators are shown connecting the air spaces with the front and side walls of the loading platforms.

The most readily applicable method of reducing the heat conductivity of the walls themselves is to introduce voids close to the surface; that is, to build the wall surfaces of porous bricks or of tiles, which not only are porous, but which contain numerous voids and are therefore very poor heat conductors. In the cases of several recent batteries, the method just mentioned has been tried and has been very successful. The poor conductivity of the tile and porous brick surfaces reduces the amount of condensation. Such condensation as does occur is not only absorbed by the porous bricks or tiles and thus becomes invisible, but by its latent heat it raises the temperature of the surfaces of these bricks and tiles to the dew point. Of course, such bricks or tiles can absorb only a limited amount of moisture, but in the cases in which it has been tried, this capacity for absorbing moisture has never yet been reached, for from time to time conditions are such as to permit the evaporation from the tiles and bricks of part of the moisture which they have previously absorbed.

Not only has this method of tile lining been applied to the wall surfaces but to the ceilings also. A design of tile roof for installation in ceilings supported by reinforced bars is shown on sheet 4 of mimeograph 109. This system of ceiling tiles consists of alternate rows of two kinds of tiles, one shaped like the letter X and the other trapezoidal. The X-shaped tiles are about 6 inches high, 5 inches wide on the base and at the top, and about 3 inches thick at the middle, both the top and the bottom halves having an air space running through them. The trapezoidal tiles are about 3 inches high, 7 inches wide at the base, and 9 inches at the top. They have three air spaces through them. When placed in the ceiling, the concrete extends in a dovetail down over the trapezoidal tiles and between the top halves of the X-shaped ones and this dovetail contains the steel reinforcing. By its shape, this concrete extending downward supports the X-shaped tiles through the dovetail forming the upper half of the X, and in turn the dovetails formed by the lower half of the X's serve to hold up the trapezoidal tiles. This system of tile ceiling thus permits reinforcing bars to be inserted at intervals of about 12 inches center to center; it holds the ceiling tiles absolutely securely; and presents on its visible surface a flat smooth tile surface.

Another method which has been tried successfully in some of the smaller batteries—that is, batteries where the walls are thin—is to introduce in the body of the wall, a few inches from its inside surfaces, layers of tiles. Where this is tried, however, a method for draining from the tiles water which may seep into them must be provided.

Another and still more radical application of the principle of making the walls of magazines poor conductors, is to build the shell rooms and powder magazines as independent houses within the open magazine spaces. These interior magazine houses are built with thin walls lined on the inside with porous brick; they are covered with roofs, waterproof on the outside and lined with porous material on the inside. Furthermore, in order to prevent condensation on the floor, due to the conduction of heat away from it to the concrete mass below, tiles are built into the floor immediately below the granolithic floor surfaces and similar layers have been designed for installation in the concrete shell tables slightly below the upper surface of these shell tables. (See sheet 3, mimeograph 109, and Plates XVII, XX, and XXII.)

In order to prevent, as far as possible, moist air from getting into the magazine houses while it is passing over and warming up the outer surfaces of their walls, these interior magazine houses should be furnished with solid doors and, for use at certain other times, with grating doors also.

A battery built in the manner described, well ventilated, with 2-foot air spaces passing around the main rooms and magazines and connected with one another and with the outside air by corridors, stairways, ventilating tubes, etc., and with the interior of the magazines and main storerooms tile lined, should remain perfectly dry under all weather conditions, provided that the ventilating system is properly operated. Whenever the atmospheric temperature is below that of the battery, it is advisable that the doors to all air spaces and other ventilating openings be kept closed and that the battery itself be opened no oftener and no longer than is absolutely necessary.

When, however, the atmospheric temperature is above that of the battery, the circulation of air, at least through the air spaces and over and around the independent magazine houses, should be encouraged to the greatest extent possible, so that the battery may be warmed up as quickly as possible; this being based upon the principle heretofore stated that anything that tends to raise or keep up the temperature of the wall surfaces of an emplacement tends to reduce condensation. The rule may therefore be stated that *the ventilation system should be so manipulated as to encourage the passage of air through the battery when the air is warmer than the wall surfaces of the battery, and will, therefore, tend to warm up the battery, and so as to discourage the passage of air through the battery when the air is colder than the wall surfaces.*

As a means of increasing the circulation of air through the battery when the temperature conditions are suitable, some officers have thought it well to provide windsails, the tubes of which can be inserted into ventilators so that the wind will blow down into the interior of the battery. Others, for a similar reason, have provided at the outlets of certain ventilator shafts opening on the top of the battery, cowls similar to those sometimes used to improve smoky chimneys. Of course, all such arrangements as cowls and windsails must be removed whenever the guns are to be fired, even in target practice.

The introduction of air passages around rooms and magazines, of both solid and grating doors, and of ventilating pipes leading to openings around the walls of the loading platform which can be closed or opened at will, while it has made possible complete control of the ventilation of the battery has, of course, somewhat complicated this control. The greatest efficiency can be secured from these appliances only by proper manipulation, that is, by opening or closing at the proper time. Up to the present time such proper manipulation has seldom been possible to secure. Consequently, the writer is not in favor of adding windsails and cowls to the ventilation system of batteries, and believes it is better and safer to restrict the ventilating system to the doors, windows, air passages, and a few ventilating openings. It should be easy to insure that the ventilators on the loading platform and the solid doors of the air spaces should be opened in warm weather and should be kept open for some time. It seems, however, too much to expect that they will be opened and closed frequently, or that good judgment will be shown in selecting the times when they will be opened and closed. With the comparatively small force kept in time of peace at our seacoast batteries, and with the multifarious duties incumbent upon the officers, it seems impracticable to rely upon the proper manipulation of a complicated system of ventilation. Simplicity, therefore, rather than complication, should be aimed at and the installation of complicated apparatus is not only a needless expense but frequently it will be so manipulated as to do more harm than good.

If it could be insured that all the officers serving at batteries were properly instructed in the physical laws governing condensation, the proper manipulation of a ventilating system might be expected, but it has been found that not only are such principles not understood by the junior officers, but even that improper instructions are sometimes issued from the War Department.

As an example of the latter, the following should be noted. A number of years ago the Engineer Department was requested by the Artillery to install at all batteries thermometers and psychrometers, the psychrometers for outside use and the thermometers for inside use. Pamphlets giving instructions for the use of these thermometers and psychrometers were issued from the War Department and in my opinion these instructions were based on fundamentally wrong principles.

The instructions directed that the battery commanders should frequently make readings of the psychrometers and thermometers and that whenever the dew point of the atmosphere was found by the psychrometer to be above the temperature of the interior of the battery, as shown by the thermometer, the battery was to be kept tightly closed. Whenever, on the other hand, the dew point of the atmosphere was found to be below the temperature of the battery, the doors were to be opened and ventilation was to be encouraged.

Apparently these rules were based upon the idea that the introduction of air into the battery when the dew point was below that of the temperature of the battery would cause no condensation and would probably result in the evaporation of such moisture as was present in the battery. As far as this goes, the theory is correct, but it should be noted that on the seashore there is usually no material difference between the dew point and the atmospheric temperature. Consequently the dew point can be materially lower than the temperature of the battery only when the atmospheric temperature was lower and the carrying out of the instructions would result in the opening of the battery for ventilation only when the atmospheric temperature was materially cooler than that of the battery. The result would necessarily be the continued cooling of the battery and, if the principle were carried far enough, there would be fewer and fewer times when it would be permissible, under the rule, to open the battery. The carrying out of this system, while it might lead to the occasional evaporation of some moisture, would continually cool off the battery, and would, therefore, tend to increase the condensation when, on a warm moist day, it finally became necessary to open it.

In fact, I do not hesitate to say that the principles upon which the instructions were based were fundamentally wrong, since, as has been shown above, the proper use of the ventilating system must be based upon doing all that is possible to warm up the battery and to keep it from cooling off.

Reducing Condensation at Older Batteries.

As has been stated, many of the older batteries constructed were designed without any idea of the extent to which condensation would take place. Where condensation in these old batteries has been most objectionable the dampness has usually been increased by seep water, and the methods of preventing this have been discussed under that head. In many cases, however, where undue seepage did not take place, condensation was very bad and steps to ameliorate this condition became necessary. The most effective means to accomplish this have usually been based on the idea of improving the ventilation of the battery and the circulation of air through it. The first batteries that were constructed were, of course, provided with windows and doors where considered necessary. When the battery was in use these doors and windows were open, permitting a circulation of air. When the battery was not in use, in order to insure the safety of the contents of the battery, these doors and windows were closed. As only solid doors and solid shutters had been provided, the closing of the doors and windows practically stopped the circulation of air through the battery.

In order to avoid this, it has become customary in all new batteries to provide solid and grating doors at all doorway openings and to provide gratings at all windows so that both the doors and windows can be left open for ventilation, the gratings providing for the safety of the contents of the battery.

This same idea has been applied to many of the older batteries, it having been the policy of the department for a number of years to provide gratings for the door and window openings of such batteries as fast as funds permitted.

Of course, to be most efficient as a means of preventing condensation, the solid doors and windows of these older batteries should be manipulated in the same way as has been mentioned above for the air-space openings—that is, they should be kept open whenever the outside air is warmer than the temperature of the interior wall surfaces, and should be kept closed whenever the outside air is colder. Such a careful manipulation has not been possible to attain, but where it has been possible to induce the battery commanders to leave the solid doors and window blinds open, even continuously, conditions as to condensation have been much improved.

It is a well-known fact that in many cases batteries that had been notoriously wet and uncomfortable, when provided with solid doors habitually kept closed, have been made fairly dry by the mere expedient of adding gratings and leaving the solid doors and windows open all the time. Of course, occasionally during the first warm, moist days of early spring some condensation has been present, but the continuous circulation of air as the winter changes into spring has been sufficient to begin the warming up of the batteries, so that by the time the weather conditions are such as to be favorable for condensation the difference in the temperatures of the wall surface and of the outside air will be so small as to be rapidly overcome by the latent heat given off by a small amount of condensation. Consequently, except for occasional days in the early spring and summer, such batteries have been fairly dry. When, therefore, there is any doubt as to the possibility of having the solid doors and windows opened and closed at the proper times, the doubt should be solved by leaving them always open.

HEATING.

Until within the last few years the idea of heating fortifications artificially as a means of preventing condensation was not given consideration. To be sure, oil lamps or oil stoves had sometimes been used to dry out the air in mining casemates and thus reduce the leakage in the electrical apparatus. Stoves had sometimes been placed in the plotting rooms of batteries and fireplaces had been provided in some of the rooms intended for offices, but a general heating up of emplacements was not considered practicable.

In 1903 and 1904 some suggestions were made and experiments were tried (see mimeograph 61, supplement 8) as to the effect of heating up a battery in the early spring by means of an apparatus for heating the air, a fan for blowing the heated air into the battery, and canvas air ducts for conducting it were needed. Apparently this plan was efficacious when tried, and it was thought that one or two applications in the early spring of each year should warm up the battery sufficiently to prevent condensation during the following summer. The apparatus, however, was unwieldy and its general adaptation was not tried.

The next step in connection with the heating up of batteries followed the adoption of gasoline-operated generating sets as the standard power plant for battery use. The cylinders of the engines of the sets are cooled by circulating water and, except in a very few cases where sea water is available, economy in the use of this circulating water requires that it be itself cooled by air. That is, the circulating water, after being warmed up by passing around the cylinder walls, is pumped through a radiator cooled by a blast of air driven by an electric fan. The air coming from this radiator is, of course, heated up as it cools the water and when the radiator was first used in the same room as the power plant it soon heated the air of the power room so as to make it too hot for the attendants. It therefore became necessary to install the radiator in a separate room and under such conditions that it could draw air from the power room and force the heated air outside through a window or flue provided for the purpose. It thus served not only to cool off the water but to ventilate the power room.

The availability of a blast of hot air such as that given off by the radiator naturally suggested the possibility of using this blast in the spring and early summer for warming up the wall surfaces of an emplacement and thus preventing condensation.

The first arrangement of this kind proposed is shown in mimeograph 109 (Plate XXII) where, near one end of the battery, there is shown a power room. The radiator is to be so placed that its hot air blast can be passed through a large flue extending from one end of the battery to the other in front of the line of magazines and storerooms. Openings into this flue are shown at various places and it was stated in the text accompanying these plans that in these openings there were to be installed dampers so that the flow of hot air into any particular part of the battery could be regulated as desired.

The first battery built on the general type of mimeograph 109 was Battery Randolph at Honolulu. In this battery there was substituted for the circular flue, a passageway about 2½ feet wide by 6½ feet high, having doorways at numerous places. Doors placed in these doorways were installed to take the place and perform the function of the dampers suggested by the mimeograph. The use of a passageway was considered preferable to the large flue because it permitted men to pass through and clean it out when necessary.

After this battery was built, however, experience showed that the climatic conditions were such at the locality, and generally in the tropics, that condensation does not occur, consequently, the provision for warming up the battery was an unnecessary precaution. It was, therefore, not installed in the large batteries subsequently built in the Philippines and on the Canal Zone.

But the idea of using this hot blast of air for warming batteries is a perfectly practical one and should hereafter be installed in all batteries constructed in continental United States or wherever climatic conditions are such that condensation occurs. In fact, this idea has been utilized in all the long-range 12-inch batteries recently constructed in this country.

If the blast from these generating sets is allowed to spread at all times through the emplacements, the heating would frequently be overdone and the rooms and magazine spaces would become too warm for comfort and possibly hot enough to affect the powder in storage. Wherever therefore, a radiator is so installed as to make possible its use for warming up the battery, this disposal of the air should be an alternative only and thoroughly under control by doors or dampers. Normally the hot blast should be discharged to the outside air through flues or passageways provided for the purpose and only occasionally should it be blown into the battery.

It is further proposed in future emplacement construction to provide means so that the hot air blast can, when needed, be used to melt any ice, snow, or sleet that may fall or form upon the gun carriage or in its vicinity.

VENTILATION.

Wherever human beings are working, ventilation is necessary to provide fresh air for breathing and to carry off the vitiated air which has been breathed. For this reason, to some extent at least, the ventilation of the magazines and galleries of emplacements is necessary.

In general, the number of men working in the interior of batteries is small, and since it has not been customary to provide dormitories in the emplacements built in the continental limits of the United States, the circulation of air coming through the doors and the windows necessary for the entrance of light have been found sufficient for the detachments working inside. The encouragement of ventilation has, therefore, not been found necessary by any circumstances connected with the health or physical condition of the men.

In the tropics, however, different conditions exist, and this is specially true of the Panama Canal fortifications. Owing to the exposure to hostile fire of the sites where many of the Panama batteries are built, it was considered necessary in many cases to build them almost of the type of subterranean tunnels and rooms. The atmosphere of the Isthmus is always quite warm and usually nearly saturated and, therefore, for the comfort as well as for the health of the garrison, it was considered necessary to provide artificial ventilation for these batteries.

Thus it was thought necessary to install in by-passes at the entrances to certain batteries (see designs of Batteries Burnside, Buell, and Warren, Panama fortifications) large 5-foot fans which would draw air from the outside and force it into the batteries. The various corridors were provided with solid doors which could be closed, and by proper manipulation of these doors this forced air could be prevented from running back into the entrances from which it came and could be distributed as desired through all the rooms and galleries of the batteries.

In certain other places where a number of men might be expected to be gathered together, such as plotting rooms and latrines, small suction fans operating in air ducts were installed to draw off the vitiated air and force it outside.

In the portions of this chapter in which the subject of condensation was treated, the importance of sufficient ventilation as an aid to decreasing condensation was discussed. It need not, therefore, be repeated here.

CHAPTER X.

BLAST EFFECTS.

One of the greatest difficulties with which the fortification engineer has had to deal in connection with modern fortification work is the terrifically destructive effects of the discharge of high-power guns. Not only is this blast effect uncomfortable and dangerous to the personnel, but it does great material damage. The sodded slopes in front of the gun are frequently torn up and, occasionally, even the concrete blast aprons are seriously cracked and damaged. In extreme cases thick metal blast aprons have broken away from their fastenings. Window panes are broken, even at considerable distances from the gun, and in the vicinity of the gun, window sashes are frequently torn out bodily. Doors are burst open, sometimes due simply to the breaking of the locks, but in many instances doors have been split open or have been bodily torn from the hinges. Not infrequently, wooden doors as much as 3 inches thick have been split in two. Sometimes where small houses have been located in the vicinity of the gun and the doors and windows were not open when the gun was fired, not only have these doors and windows been destroyed, but the very walls and roofs have been seriously injured. In extreme cases, interior waterproof ceilings have been broken down or seriously damaged. Electric lights are destroyed, sometimes by the breaking of the filaments, and sometimes by the shattering of the bulbs.

It seems to have been thought for a considerable time that the principal blast damage was due to the wave of pressure coming from the muzzle of the gun, but later study has shown that though in front of the plane of the muzzle the greater part of the damage may be due to this wave of pressure, yet in the rear of the muzzle, and especially in the interior rooms and passageways, damage appears to be done more by a wave of rarefaction following the first wave of pressure. When a gun is fired, the air in front of the muzzle is blown forward. A vacuum is formed and the attempt of the surrounding air to rush in and fill this vacuum causes a wave of rarefaction to proceed outward from the gun. It has been shown that this wave of rarefaction may be reflected much in the same way that sound waves are reflected and where the original and reflected waves are in accordance, greatly increased damage may be done. In a few cases the damage seems not to have been due directly either to the wave of pressure or the wave of rarefaction, but rather to an excessive vibration set up as the resultant of these two and the following waves.

Often also the blast effects are quite erratic, if not inexplicable. There have been occurrences where a gun fired at a certain azimuth or elevation does no damage at all. A very slight change in either azimuth or elevation will result in great blast damage and a very slight additional change will again reduce the damage so much that it may be considered as negligible. Occasionally, also, where several successive shots are fired without any change whatsoever in the aiming of the gun, the blast from some of the shots has done considerable damage, while that from others has done none at all.

As indicating some of the peculiarities of blast effects, I will mention a few incidents which have come to the personal attention of the writer. Some years ago, during target practice at Fort Monroe, there was in rear of one of the flanks of a 12-inch battery a small frame house used as a tool house. Orders had been given that all the doors and windows in this house should be opened before the guns were fired, but through some mistake this was not done, and the first gun was fired with all the doors and windows closed. The result was that the windows on three sides of the house were all badly broken, and the door which is on the fourth side was split. The window glass was all drawn outward from the windows and the entire effect was as of an explosion inside of the house.

During the summer of 1906 at Fort Monroe a recently constructed 12-inch battery had its guns proof-fired. This battery is based essentially upon the plans shown in mimeograph 66 (Plate XX), there being a number of rooms located on the magazine level under the loading platform of the battery and having windows opening on a corridor under the rear of the loading platform. Before the guns were fired all these windows were opened, but one of them seems not to have been securely fastened back and, as a result of the fire of the first shot, it closed. When the second shot was fired the glass in this window was pulverized and was all sucked outward, that is, to the rear, under such pressure that some of it was drawn horizontally a distance of fully 30 feet, while falling a vertical distance of only 5 or 6 feet. Where the windows were opened and fastened open, no damage was done.

At one time at the mortar battery at Fort Monroe (see figure 4, Plate XXVII), the four guns of one pit were fired in salvo and in a direction which threw their line of fire approximately over the doors entering the magazine. There had been placed in the lobbies of this pit a short time before a number of blue prints mounted in picture frames with glass fronts. Nearly all of these glasses were broken at the first fire, the glass being always drawn out. In some cases, even the blue prints were sucked off the boards to which they were attached, and in another place, where only about half of the glass was drawn out of the frame, the blue print was sucked partially through the hole in the glass. At the same time, quite a number of the sections of the corrugated damp-proof ceiling were drawn downward as if by suction from below.

Another somewhat unusual effect of the blast occurred in one of the powder magazines at the Fort Monroe mortar battery. This magazine was about 50 feet long by 10 feet wide and was entered by a 3-foot door, situated at one end and close to one of the side walls. The magazine had recently been divided up by wooden partitions into a number of stalls for experimentation with the zone storage system. Before the mortars were fired, the door to the magazine was left open, but in spite of this precaution serious damage was done. The stall partitions near the center of the magazine were practically torn to pieces, those about half way between the center and the ends were slightly damaged, while those nearest the ends were not affected at all. This indicated clearly that the effect of the blast had been to set up in the magazine a vibration of air, the ends of the magazine acting as nodes and the center as the ventral section.

A few years ago, there was built within the crater of an extinct volcano in the Hawaiian Islands a mortar battery intended primarily for land defense. This battery consisted of four mortars—that is, two pits of two mortars each. Within the traverse between the pits there were located certain rooms intended for fire control and power purposes. The mortar pits were quite small and were surrounded by high vertical walls, with a result that, when the mortars were tested, it was found that the blast effects were very serious, especially in the galleries connecting the two pits and in the rooms opening thereon. This was doubtless due to the small size of the pits and the way in which they were surrounded by walls.

Instances of blast effect were described in the Engineer mimeographs Nos. 45, 63, 81, 100, and their supplements, and also in the twenty-fifth supplement to mimeograph 48.

From the above recorded instances, from many others which have come under my casual observation, and from talks I have had with other officers of much more experience, it would appear that the blast damage in rear of a battery, and especially in its interior, is due principally to the initial wave of rarefaction and, secondly, to the vibrations of the air following this initial wave.

Interesting though a record of the damage done by blast may be, it is of value to the fortification engineer only in so far as it is a guide to him for future construction, by showing him what conditions should not be repeated. Frequently, in the preceding chapters, references have been made to damage due to blast effects and to the modifications which have been made in the designs in an attempt to avoid blast damage in the future, or at least to bring that damage within permissible limits.

In general, it may be said that it has been found that the more nearly open and free of obstruction the space around the gun is the less will be the blast effect, for under such conditions the outside air may rush freely in to fill the vacuum caused by the discharge of the gun. This is very clearly shown from the fact that the blast effects in the more modern mortar batteries which are open freely to the rear are much less than in the older batteries where the mortars were located in pits completely surrounded by high parapets. Furthermore, the wider platforms of the more modern direct-fire guns have caused the blast effects in such emplacements to be much less than with the contracted platforms of the older type emplacements, and this in spite of the increase in the size of the guns.

The precautions that should be taken to prevent blast from injuring or damaging houses, doors, windows, and other objects depend upon the relative position of the object and the gun, the size of the gun, and the direction in which it is usually fired. In general, except in their immediate vicinity, no material blast damage will be caused by small or medium caliber guns; it is only from large caliber guns that great blast damage is to be feared.

In localities 200 yards or more from a large caliber gun, except in a direction in which it is possible for the gun to be fired, it is usually not considered necessary to take any special precautions in house construction, but it is well, whenever it is known that a gun is to be fired, to open the doors or windows of all houses or other structures. If the doors and windows be opened, it is not probable that damage will be done to them, but opening the doors and windows has sometimes transferred the blast effects to the interior of the building, and in a few cases has resulted in having the doors of closets broken or pulled open.

Occasionally, also, the plaster ceilings of houses have fallen when a gun situated even more than 200 yards away has been fired, but to what extent this has been due to the blast waves sent through the air, and to what extent to vibrations transmitted through the ground, can not be definitely determined. Whatever the cause, so much damage of this character was done in certain locations by the discharge of heavy guns that it became customary several years ago to use as the ceilings of officers' quarters at seacoast forts not ordinary plaster on laths, but a specially manufactured ceiling composed of stamped and painted sheet metal nailed to the ceiling rafters.

Within less than 200 yards of a large caliber gun it is necessary, as a rule, to take special precautions in building construction. Especially is this true of plotting rooms and battery commander stations when built in or close to either direct fire or mortar batteries.

When located well in rear of the plane of the muzzle, and when all the doors and windows have always been opened during firing, frame buildings and buildings composed of plaster on metal lathing have as a rule been fairly successful in withstanding the effects of blast. But in a number of cases where such buildings were placed on the rear slopes of the traverses of mortar batteries of the 1894 type (see figure 4, Plate XXVII) and the mortars were fired obliquely toward them, they have been much damaged. The frame buildings were badly wrecked and the plaster was cracked or shaken off of the plaster buildings. Reinforced-concrete structures in such locations have usually stood the blast perfectly.

Windows are, of course, especially liable to be damaged by blast, the window panes being cracked and broken or, in extreme cases, the sashes being broken to pieces. In order to avoid damage to the windows they should also be open when the gun is fired. When quite distant from the gun, the ordinary vertical sliding sashes that leave free about half the area of the window opening have usually withstood the effects of the blast, though sometimes some of the panes have been broken. In more exposed locations the window sashes that have stood the blast effect best are those rotating about vertical axes, so that when the gun is about to be fired, the windows can be opened and can be set so that the motion of the air wave is parallel to the window surface and not perpendicular to it. In the rooms opening on the corridors under the loading platforms of heavy guns (see Pl. XXII), a method of mounting windows that has been found particularly serviceable has been to rotate each sash about a vertical axis passing through its center, the sash rotating on special pivots inserted in the top and bottom of the window frame (see sheet 5, Mimeograph 109).

In general, it has been found advisable anywhere in the vicinity of fortifications to use a better quality and thicker glass than that ordinarily used in windows. In some special locations it has become necessary to use wire glass. This was especially true in the glass roofs over the observation rooms at the top of the fire-control towers where they were built in the vicinity of gun batteries, and in the windows of the observation openings of the battery commander stations of mortar or heavy direct-fire gun batteries.

It should be unnecessary to state that whenever guns are to be fired, the doors and windows in all buildings, permanent and temporary, in the vicinity of the battery should be opened, and should be securely fastened open, so that they may not be closed by the blast of one shot and be destroyed by the next.

It has been customary, when a battery is turned over by the engineer department to the Artillery, that drawings showing certain details of the battery be furnished to the commanding officer. In addition, copies of these drawings were usually posted in the battery. These drawings were usually in the form of blueprints, and for many years it was customary to mount them in picture frames and hang them on the walls of the rooms or of the corridors of the batteries. In the older batteries it was not unusual for the glass in these frames to be broken by the blast, and sometimes the frames themselves were badly injured. So much damage of this character was done that a few years ago it was decided that thereafter these blueprints, instead of being framed like pictures, should be attached to sheets of galvanized sheet metal. The blueprints are glued to the metal sheets, are varnished to protect them from dampness, and are then posted in the batteries. (See Mimeograph 103.)

In the early days searchlights were sometimes injured by blast. Fortunately, however, this did not occur very frequently, because in order to prevent the searchlight beam from interfering with the sight of the men at the guns or in the battery commander stations, the searchlights were placed at least a few hundred yards to one flank or the other of the battery, and this was usually sufficient to preserve them from the effects of the blast. The damage to the searchlights which has happened has been not the breaking of the mirrors, which are so mounted to prevent this, but the destruction of the so-called front doors. In the older form of searchlight mechanism used prior to about five years ago, a front door was necessary in order to keep the air currents from causing the arc to flicker. However, with the modern high intensity searchlights, such front doors have been found to be unnecessary and the use of them has been abandoned, so that in the future there will be no front doors to be injured.

As regards the effect of blast on the personnel, there would appear to be many contradictions. For instance, it is found that the detachments with a little cotton in their ears can stand around the base of the gun carriage or on the sighting platform of the 12-inch, 14-inch, and 16-inch guns without any special discomfort, although the destructive effect of the blast is very great in those localities. It is further found that, as far as the effects on the nervous system are concerned, the shocks of the 5-inch and 6-inch guns appear to be much more powerful than those of the 12-inch and 14-inch guns, although the intensity of the blast and the material damage is vastly less.

In an attempt to study quantitatively the effect of blast from guns, there was invented nearly 20 years ago by Col. (then Capt.) Edward H. Schulz, Corps of Engineers, a so-called "blast meter," which is described in the first supplement to Mimeograph 81 and in the drawings pertaining to it. This first blast meter was based upon the idea that it was the wave of pressure that did the greatest amount of damage, and as originally constructed, it measured pressure only

Later, however, it was modified by Col. Schulz so that it could be adjusted to measure rarefaction.

Comparatively recently Col. Schulz has again taken up the study of the measurement of blast effects, and has invented a new type of blast meter the readings of which depend upon the breaking strength of paper stretched over holes of different sizes. This last form of blast meter is illustrated and described at some length in a recent number of Professional Memoirs (Vol. XI, No. 57).

The readings of these different forms of blast meters have, as a rule, been fairly consistent one with another, but unfortunately they do not seem to bear any well-defined ratios to the physiological effects upon individuals or the amounts of physical damage done by the blast. So far as concerns damage to the superior slope of the parapet and to objects in front of the plane of the muzzle, the readings of the blast meters seem to be fairly in accord with the severity of the blast effects, but when it is a question of the damage done in rear of the gun or in the rooms and interior passage ways of a battery, the blast meter indications would appear to be no criterion upon which to base an estimate of the damage which will be done.

CHAPTER XI.

USES OF ELECTRICITY IN FORTIFICATIONS.

It is proposed to give in this chapter a brief outline of the application of electricity to fortification uses, but without going at all deeply into the subject of electrical engineering.

Historical.

When, about 1890, the construction of our modern fortifications was begun, the use of electricity for lighting and power purposes had reached a considerable commercial development. Consequently, we find arrangements for the use of electricity in the first emplacements built, and one of the very earliest of the Engineer Department mimeographs gives a description of the electric lighting plant installed in the San Francisco mortar battery, the earliest mortar battery begun.

Although it had been planned to use electricity for lighting purposes in all the new emplacements, the funds available for that purpose were, prior to the Spanish War, so small that comparatively little was accomplished. Under the spur of the excitement caused by the sinking of the *Maine* and the practical certainty of an early war with Spain, Congress made a large appropriation to prepare the country for defense. Out of this so-called "National defense fund," and other emergency appropriations made shortly thereafter, a large amount was allotted for fortification purposes and a considerable proportion of this was expended in the purchase and installation of electric plants, the building of power houses, etc.

As is the case with all emergency work, the electrical installations were hurriedly made. Almost any kind of a boiler and engine that was available was purchased, and it is needless to say that time proved that a number of these hastily installed plants were quite unsuited for fortification use.

As a general rule the plants installed were operated by steam, though another variety of engine purchased quite extensively was the Hornsby-Akroyd oil engine. Occasionally these plants were placed in already existing rooms. More frequently, however, they were installed in small power houses hastily constructed in rear of and under the protection of the emplacements.

The first plants were intended for lighting only and were, in general, merely large enough to furnish power for this purpose. However, after the electric plants were once installed, it was but natural that the idea should arise of using them for other purposes than lighting, such as furnishing power for electric motors. The first step of this character was the use of electric motors to operate the old balanced platform hoists in the earlier 8 and 10 inch emplacements, and as these platform hoists were removed and replaced by chain hoists, motors for operating these chain hoists were installed at the same time.

At first, nearly all matters connected with the design and installation of electric plants were left to the constructing officers, and as a natural result the installations in different sections of the country differed greatly. It became evident that some effort must be made to standardize electrical equipment and bring it to some degree of uniformity.

It is, of course, not practicable to secure absolute uniformity in all our electric plants at all fortified posts, for the conditions to be met with vary too greatly; but the advantages in having the fewest possible number of different types is too obvious to require argument. That the type of design at one fort should be similar to that at others is advisable, because Artillery officers and enlisted men are frequently transferred from one station to another, and it is, of course, desirable that they should find the electric installation at the new station so nearly like that at the old that they will be able to apply at the new post the knowledge which they obtained at the old.

But, though it is desirable that the installations at the different forts should be somewhat similar, it is by no means as important as that the installation in the different plants at any one fort should be alike. Many reasons may require that the personnel in charge of a plant in one battery be called quickly to take charge of the plant in another battery at the same post, and the plants should be so much alike that these men as they go from one to another will know exactly how to operate them.

This is especially true of switchboards; that is, the switches used for the same purpose should have the same relative position on all switchboards. Indeed, this question of similarity of switchboards is believed by the writer to be so important that he would, in some cases, unhesitatingly recommend the duplication of existing switchboards rather than the introduction of a possible improvement on a single new switchboard unless it is intended that a similar improvement shall shortly be added to all.

As early as 1896 the Board of Engineers gave consideration to the subject of electrical installations and submitted to the Chief of Engineers a report published in Mimeograph No. 13. This mimeograph, which is now practically obsolete, discussed the general subject of the installation of emplacement electric plants and submitted specifications of a rather general character for the guidance of constructing officers. Steam power seemed to be preferred, although the oil engine was favorably recommended. Storage batteries, or as they were called at that time, "accumulators," were recommended as reserves. It was pointed out that without some such reserve it would be necessary, every time it is desired to light up a single room of an emplacement to start the steam plant; with a storage battery in commission all that is necessary is to throw the proper switches. For the wiring, the board recommended ordinary okonite covered wire and suggested the use of pipe conduits wherever the wiring was to go through masonry. Although, in general, all the lights were to be controlled by a single switch at the main switchboard, branch circuits controlled by separate switches were suggested in special places and the necessity was noted of having fuses at the points where the circuits branched. An estimate was given of the number of electric lamps required and it should be noted that this is a very small fraction of those now considered necessary.

In 1900 a board of Engineer officers was organized by the Chief of Engineers for the purpose of considering the subject of electric installations, and this board continued in existence for a number of years, with, however, changes in membership from time to time.

The first report of this board is published in Professional Papers No. 27, Corps of Engineers, which is well worth reading. It recommended steam as the standard prime mover. The electric system was to be direct-current. Storage batteries were to be used as reserves, and in order to be able to charge the batteries fully without causing the dynamos to be operated at exceedingly high voltages, the plan was suggested of cutting the storage battery in halves and charging these halves in parallel, but connecting them in series for discharge and use. A form of switchboard for accomplishing this was shown in the report, the wiring of which was shown in a diagram.

The principle of charging the storage battery in halves in parallel and discharging it in series is an excellent one, but the method of regulating the voltage recommended by Professional Papers No. 27 was not the best one.

The voltage of a storage battery cell, and therefore of an entire storage battery, when first charged is quite high, but as the charge is used the voltage is reduced. The battery is still in usable condition when the voltage has dropped by as much as 15 per cent of its maximum. Now, it is evident that where a storage battery is to be used for lighting purposes, a sufficient number of cells must be placed in it to leave its voltage as it approaches a state of complete discharge, slightly greater than that required for lighting purposes or, say, 115 volts at the switchboard. This means that when the storage battery is freshly charged its voltage will be some 15 or 20 volts too high. If while in this condition, the full power be turned on a small number of incandescent lights, they will quickly be burned out.

In practical use, therefore, it is necessary to reduce the voltage of the storage battery and this can be done in two ways, by the introduction of rheostats in the circuit, or by cutting out a few of the cells. The former method was the one recommended by Professional Papers No. 27.

Three rheostats are shown, a small one in circuit with each half of the storage battery for use in regulating the voltage of that half during the charge, and a large one in the main circuit beyond where the two half circuits are joined together for general use. That is, the main current passes always through a large rheostat. While the battery is being charged, the current divides and half runs through each half of the storage battery and through one of the smaller rheostats. When, during discharge, the two half circuits are put in series, the three rheostats are, of course, in series and as much resistance can be put in as may be necessary.

With an open circuit, the voltage at the bus bars is that of the storage battery, whether or not all the resistance of the rheostats be connected in. It is intended that when a load is placed upon the battery the voltage shall be regulated by the main rheostat, resistance being cut out as the load is increased. This means, however, that every time the load is increased or diminished, the rheostat adjustment must be made. If it is not, and the load be suddenly decreased, a few electric lights left in circuit will be liable to burn out; if the load be suddenly increased, the lights will get very dim. Where the storage battery was used for furnishing power for lights only and where the lights could be turned on or off only in groups, the case was not so bad, but where the same storage battery was used for furnishing power for operating hoists, the load of which was extremely intermittent and irregular, this system required that there should, at all times, be a man at the switchboard, practically with his eyes on the voltmeter and his hand on the rheostat wheel. For these reasons, in systems combining light and power, this arrangement did not work well and it became evident that a change must be made.

After a year or so of attempting to operate the storage batteries with the voltage regulated by rheostats, and at the same time experimenting in a few places with the end cell method of regulating the voltage, the latter was found to be preferable and was introduced in all electric plants about 1904 and 1905.

In the end cell method of regulating the voltage there is, on the switchboard, a so-called end-cell switch, consisting of a number of points to any one of which the switch can be turned. These points are connected successively to the end of the battery and to the connections between the successive cells. By turning the end cell switch to the point corresponding to the end of the battery all of the cells are placed in series. By turning it to the next point, the end cell is cut out; to the next point, two cells are cut out, and so on.

When the storage battery is first charged, the voltage of its cells is high and all of them are not required to give the proper voltage, so the end cell switch is turned to such a point as to place in action only as many cells as are necessary. As by use the voltage of the battery gradually decreases, one cell after another is added to the circuit, so that the terminal voltage of the portion of the battery used remains practically the same.

In the switchboard arranged for use with the end cell switch method, the same rheostats are needed as before because they are all necessary during the process of charging, but the connections are so made on this switchboard that when the main battery switch is thrown to discharge, the small rheostats are left out of the circuit and the main rheostat is short circuited.

One of the great difficulties found in maintaining the early fortification lighting plants was that they were used so little that it was difficult to keep them in order, for machinery of all kinds deteriorates much more rapidly when not in use than when in use. The question then arose as to whether it might not be desirable to use these plants for regular garrison lighting. This would not only insure that they would be kept in order, but it would also give the garrison a much needed experience in taking care of the plants.

This subject was referred for consideration to the Board of Officers above referred to and they submitted two reports on the subject, one published as Mimeograph No. 41 and the other as a Supplement to Professional Papers No. 27. In the former, the lighting of garrisons by fortification plants was recommended under certain conditions. The latter report related principally to the method of lighting garrison buildings when at considerable distances from the fortification plant. For such cases, the use of alternating current was recommended, this to be obtained from the direct current by the use of motor generators. Suggestions were also made in this report as to the use of "boosters" for reinforcing the voltage of direct current lines at points distant from the plant so as to make up for the line loss. The board further recommended that duplicate generating plants be installed as reserves rather than storage batteries.

In 1903, the board submitted another report published as Mimeograph No. 75, discussing according to the standards of the times the relative advantages and disadvantages of direct current and alternating current for central plants, and inclining to the opinion that a direct current installation was generally preferable.

In 1906, in the Taft Board report, the subject of electrical installations is touched upon and a central plant is recommended for all fortified posts, with reserve plants in each battery or group of batteries direct-current power is preferred to alternating current. Remarks on this subject on pages 16, 35, and 36 of this report might well be read.

Since the report of the Taft Board the installation of electric power in our fortifications has been steadily progressing and has been slowly undergoing a sort of evolution. The results of this evolution have in some respects been almost the opposite of what was evidently considered probable by that board. These developments will be discussed, each in its proper subdivision of this chapter.

ELECTRIC INSTALLATIONS.

In some important respects, the requirements which it is essential that fortification electric installations shall fulfill are quite different from those governing in commercial plants. In commercial life certainty of action, though an important desideratum, is usually not considered as necessary as economy in operation. In fortification plants, on the other hand, economy in operation is but of minor importance, as compared with reliability and certainty of action. A commercial plant is in operation day after day and all day. Economy, therefore, is of prime importance, and an occasional temporary breakdown, though it may mean a loss of time and in one or more ways a loss of money, is not an irremediable disaster. Fortification plants, on the other hand, are, in time of peace, usually run at intervals only; they find their real use only in time of action, and at such a time a breakdown will, in all probability, prove disastrous. Consequently, in selecting or designing electric machinery or fittings for installation in fortifications, care must be taken to select only those which are thoroughly reliable, and these must be installed so as to give them the maximum possible protection against injuries caused by accident or the efforts of the enemy.

The safety of an electric plant requires that it be thoroughly protected from hostile projectiles—in fact, in the early emplacements it appeared to be considered about as important to give protection to the power room as to the magazine. Consequently, in the first emplacements designed, the power rooms were located well in the interior of the emplacements in positions somewhat similar to the magazines. These rooms were dark and usually damp, and it was soon discovered that an electric plant in such a position would rapidly deteriorate. Furthermore, the electric leakage, especially on the switchboard, was considerable.

An additional trouble due to dampness arose when the attempt was made to place storage batteries in these damp rooms. (See Plates XIV, XV, XVIII, and XIX.) It was found that water would condense in the storage-battery cells, filling them in some cases to overflowing and reducing the strength of the solution. The surplus liquid had, of course, to be siphoned out at intervals and new acid had to be added to bring the solution up to proper strength. So much trouble was caused in this way in the earlier storage batteries installed in such damp rooms that it soon became customary to remove them, and the generating plants as well, to temporary buildings located outside of the emplacements, frequently in partially exposed positions.

The next step, of course, was to utilize for miscellaneous storage purposes the rooms in the emplacement which had been intended for the power plants and from which, in some cases, the electric plants had been removed. The result was that had it been found necessary to move the electric plants hastily back from their supposedly temporary locations, there would have been no place to put them because the rooms previously assigned to that purpose had been utilized for other purposes.

Beginning, however, about 1902 or 1903, a change in policy was made, and in all emplacements thereafter constructed power rooms were provided which were not only well ventilated and free from condensation but were so located as to be fairly well protected from hostile fire. (See Plates XVII and XX to XXVI.)

LOCAL AND GENERAL SYSTEMS.

In seacoast fortifications the guns are usually concentrated into small groups called batteries. The batteries are sometimes built close together and sometimes are scattered over a large area. Electricity is needed for one or more purposes at every battery but may be provided in two ways—by making the electric installation in each battery or contiguous group of batteries, separate and independent from the installations in other batteries or groups of batteries; or by making the installations in all of the batteries parts of a single large installation. The former is sometimes called the "separate plant system" and the latter the "central plant system."

If reliance be placed on the central plant system, each battery is dependent for its electric power upon an electric connection with the central plant. Not only is this, as it were, putting all our eggs in the same basket, but experience has shown that electric cables are quite subject to injury or destruction. The essential requirement of reliability, therefore, points to the adoption of the "separate plant system."

It is therefore desirable that, as far as possible, the electric installation in each large battery, or group of contiguous smaller batteries, should be practically independent of the installations in other batteries, and should not be absolutely dependent for power upon a connection with a central plant or a plant in another battery.

It is much more economical, however, to operate a central plant having power equal to the combined power of several smaller plants than it is to operate the several smaller plants independently and simultaneously. Furthermore, it frequently happens that the demand for electric power at any one battery or section of the fortifications is very small, so small in fact as hardly to make it worth while to start up the local plant. It is probable, however, at every large group of fortifications that there will at all times be some demand at some part of the fortifications sufficient to justify running the central plant on a small scale. Consequently, in time of peace, both economy and convenience point to having a central plant practically always in operation, local plants or the plants in local systems being utilized only sufficiently to keep them in good order.

Need of Reserve Sources of Power.

It has been shown that in selecting or designing any portion of a fortification electric installation, reliability and certainty of action are the prime desiderata. But, unfortunately, however great the care that may be taken in selecting or in designing electrical apparatus, an occasional breakdown is sure to occur. Should such a breakdown happen in time of action, it would be disastrous. It is essential, therefore, that in case of such a breakdown we have an additional or reserve source of power to fall back upon; that is, we must have a duplicate source of power for use in case the main source is destroyed or in case the connection with the main source is cut. In fact, we must go further and must have other means to fall back upon in case all our sources of electric power should fail.

These ideas have been carried out in our fortification construction. Thus there are usually provided two sources of electric power which are available for lighting. In case both of these sources should be cut off, all our emplacements are provided with lamp recesses and "reserve lanterns" for use in these lamp recesses. Up until a few years ago, the reserve lanterns were oil lamps; now they are merely small, portable, electric lanterns operated by low-voltage dry batteries, similar in their essentials to the flash lights in such common use in commercial life.

Similarly, our ammunition hoists are normally operated by electric power, but they are all built so that in case the electric power should absolutely fail the hoists can be operated by hand. Similar arrangements are made wherever else electric motors are installed.

The principle of having a reserve source of electric power was included in the reports of the first board of Engineer officers on electrical installations referred to above. They recommended, for each battery, a steam engine as the prime source of power and a storage battery as a reserve. The idea was that the storage battery should at all times be kept charged nearly up to the maximum, or at least that the beginning of an engagement should find it so charged. During action the steam engine itself would be used, but in case the engine should become disabled the storage battery could instantly be put into service. This was the theory of the case, but the facts are that a storage battery, to be in good condition, must be charged and discharged at fairly frequent intervals. Consequently the custom gradually grew up in peace time of running the engine only once every week or so to charge the storage battery, and of utilizing the storage battery as the actual source of power between these times of charging. This may have been convenient and may have preserved the storage batteries, but it was directly opposed to the theory of reserves.

For several years the standard type of installation was essentially like that just described, the steam engine as the primary source of power and the storage battery as the reserve. It was soon found, however, that storage batteries are expensive to install and, at least under the conditions met with in fortifications, are even more expensive to maintain. Storage batteries for general fortification use were, therefore, gradually done away with and they are now no longer standard except under very special conditions, such as in connection with the submarine mining system and in certain telephone installations.

The gradual abandonment of the storage battery required that omething should be substituted for it as a reserve source of powers. It therefore became customary, about the time of the abandonment of the storage battery, to install in our fortifications as reserve sources of power, additional electric generators operated by prime movers. These were as nearly as possible like the main sources of power.

In this character of installation, the generators forming the main source of power and those constituting the reserves are duplicates of one another. In large batteries or groups of smaller batteries the total demand is sufficient usually to require that two or more standard gasoline sets be installed. Where this is true, other and similar generator sets are installed as reserves, but it is usually not considered necessary to install as reserves as many sets as are needed in the main source of power. Thus, where two sets are required to furnish all the power that may be needed, it is usually considered sufficient to install a third set as a reserve for either of the other two. Where three sets are required to supply the maximum demand, a fourth set may be considered as a sufficient reserve.

A steam plant as the prime source of power, and more especially as a reserve, has the great disadvantage in that it can not be started quickly. In fact, an hour is about the least time upon which it is safe to count for getting a steam plant in full operation. Of course this time might be shortened by getting up fires in all steam plants at the beginning of an action and keeping these fires banked until called upon; but when we consider the speed of modern naval vessels and the extreme ranges at which actions may be commenced, an attempt to adopt this policy would mean practically that we would have to keep up fires all the time in all the steam plants. Consequently, the steam plant came to be considered as unsuitable for a reserve.

Internal combustion engines, on the other hand, can be started more quickly than the steam plants. This is only partially true of the old oil engines and is one of the reasons for doing away with them. The gasoline engine, however, has now been brought to a high stage of perfection and is in very general use; it can be started instantaneously and consequently has been adopted as the standard, not only for reserve plants, but also for the main plants in all local installations.

The first gasoline engine installed for fortification purposes was at Fort Wool, Va., during the manoeuvers of 1905. A number of defects developed in this engine and the same type was therefore not used again. A few years later, however, under the charge of Col. Harry Taylor, then district Engineer officer at New London, Conn., a number of other types were tried and as a result there was developed a satisfactory type of 25 kilowatt, gasoline actuated, direct connected, generating set. For several years thereafter, the work of perfecting this engine was continued and there are now hundreds of them in the service.

Central Plant.

For the reasons and under the circumstances stated above, there was gradually evolved the idea of having at each large fortification post a large central plant as the main source of power and to have in the different local systems the standard gasoline engines as reserves. This central plant should in general be so located as to be thoroughly protected from hostile fire. As it can well be utilized for garrison lighting in time of peace, this will insure that it will always be in good order and that well-trained men will always be available for its operation.

The character of the central plant which should be used is one upon which entire agreement has not been reached. If it were intended merely for fortification purposes, certainty of action would take precedence over economy, but since the central plant must be run almost constantly in peace time, the question of economy should be given more weight than is usually considered necessary in fortification plants. It seems to be generally considered that in most cases a steam plant is the most economical and, if the plant is large enough, use might be made of very high pressure engines with condensers. Some experts advocate a modern form of steam turbine. This, however, is strictly a question of electrical engineering and will not be further touched upon here.

The central plant should preferably be composed of a number of separate units, each unit being practically complete in itself. Yet to insure flexibility, it is desirable, if it can be done without too much complication, to so design the system of piping that any engine can be run from any boiler. The total capacity of the central plant should be at least great enough to supply all the needs of the defense while still keeping back a reserve. An additional slight reserve is also an advantage, especially should it be desirable during time of action to use electric power for garrison purposes. The individual units, or at least some of them, should be so small as to take care on an economical scale of what may be called the minimum requirements. During time of peace, as many of the units as may be needed at one time will be in operation but it is desirable that these units be utilized in some kind of rotation so that all the units will be kept in good condition at all time.

Local Plants.

In time of action it is not improbable that either the central plant may be injured or that the connections with one or more of the local systems will be cut off. It is essential, therefore, that each of the local systems have its independent source of power which can be quickly put in operation should the central plant be cut off. In time of peace, these reserve plants will be but seldom needed, but each one should be operated from time to time so as to insure its being in good condition when necessity requires that it be called upon.

Alternating or Direct Current.

In our local systems electricity is used for lighting. The voltage must be that suitable for the electric lamps to be used, and unless we are going to have different sets of lamps, the voltage of one local system must be the same as the voltage of the others. Although theoretically not necessary, it is evidently desirable that our electric lamps should be interchangeable among all batteries; that is, that all our local systems should be of the same voltage. At present the consensus of opinion seems to be that the voltage at the lamp terminals shall be about 110 to 112 volts.

As far as the lamps are concerned it is immaterial whether we use the direct current or alternating current power, and if desirable we may switch from one kind of power to the other at will, provided that the voltage of the two be the same.

Ease of connection would, in general, indicate that our motors should require the same voltage as the lamps. As far as the kind of power is concerned we can install either alternating current motors or direct current motors but we can not change instantaneously from one kind of power to the other unless our motors are so wound as to make this change possible and this, in general, is not true. Consequently, as far as our light and motor requirements are concerned, we have a free choice as to whether our electric system should be direct current or alternating current.

In the first electric installations, the storage battery was the reserve source of power. This battery necessarily gives off direct current and direct current only, and as long as storage batteries were used as reserves it was but natural that direct current installations should be exclusively used in fortification work.

The complete abandonment of storage batteries as a reserve source of power, however, leaves the question as to whether the installation shall be direct current or alternating current, dependent merely upon which is more suitable for the purposes for which electric power is required. As has been stated before, either may be used for lighting and a change from the one to the other may be made instantaneously. Either kind of power may likewise be used to drive electric motors, but as motors are wound for either one kind of power or the other the change can not be made after the motors are once installed.

The most modern form of emplacement is the one-story type in which projectile hoists are not needed. Furthermore, the Ordnance Department seems to be opposed to installing electric motors on gun carriages for traversing or elevating. Consequently, about the only motors to be used in future emplacements are those installed by the Ordnance Department on the gun carriages for retracting purposes. And for this purpose either alternating current motors or direct current motors would appear equally suitable. There is now, therefore, no reason as far as emplacement use is concerned, why an alternating current system of power is not as good as a direct current.

The alternating current system has the great advantage of permitting the transmission of electric power to considerable distances with but slight line loss. With the growing tendency to spread out the defensive works and to plan small rapid-fire batteries, range finding and searchlight stations at considerable distances from the main batteries, the reduction of line loss is becoming more important. Alternating current systems are becoming more and more popular in commercial life and it is the opinion of the writer that for general fortification purposes, the advantages of an alternating current installation far outweigh the disadvantages.

It should be noted, however, that the use of the alternating current system requires the introduction of high voltage currents, at least in the transformer room. For safety, it is considered necessary that these transformers be installed either in separate rooms or in separate alcoves in the power rooms, so that they may not endanger the personnel.

The first installation in seacoast fortifications of alternating current power on a large scale was made by the writer, then the local district engineer at Fort Monroe, Va., in preparation for the joint Army and Navy maneuvers of 1905. This was done for the following reasons: It had been decided to attempt to supply electric power sufficient to operate at least 10 searchlights, to light all the batteries, range stations, etc., to operate at the same time all the motors on the hoists and gun carriages. Sufficient electric plants to do this were not available and funds for purchasing electric plants were not sufficient. There was, however, in operation in the neighboring towns of Newport News and Hampton, an alternating current system, used for lighting and for power purposes. It was, therefore, decided to make connection with this commercial plant. This was done by means of large transformers located in the power house of a certain battery. Thence alternating current power was distributed to all local systems. In each local system there was installed a set of transformers and a motor generator. The transformers reduced the current of the alternating current system to that which was considered safe to allow to enter the local power rooms, 110 in small plants and 220 in large ones. With this reduced voltage the alternating current motors of the motor generators were operated, the generator ends giving off direct current at the standard voltage of 115. By this means it became possible with the funds available to provide sufficient electric power for all purposes.

During these maneuvers and afterwards this system worked so well that it was later decided to make it permanent. A new central plant to furnish three-phase alternating current at 2,300 volts was installed in the power plant building of the large new Coast Artillery School. The distributing cables from this system are installed in conduits and pass to the power rooms of all the local systems. Here there are installed the transformers and the motor generators. Many of the latter, now in operation, are the same as were purchased in 1905.

For the new fortifications at Los Angeles and San Diego on the Pacific coast, alternating current power was already available from a commercial source and was utilized for post lighting before the construction of the modern fortifications. Consequently an alternating current system of power was installed in the new emplacements recently constructed.

ELECTRIC WIRING AND FITTINGS.

In electrical installation for lighting purposes in the earlier batteries, the wires and fittings used were those common in commercial life at that time. The wire was the ordinary rubber-covered type, the lamp sockets were the usual sockets mounted on porcelain bases, attached to wooden blocks fastened to the walls, and the switches were commercial throw-switches with porcelain bases.

Wiring.

As has been stated, these earlier batteries were extremely damp, not only from condensation but from seep water. The moisture deposited by condensation caused large electrical leakage and the seep water showed a tendency to destroy the insulation of the wiring wherever it came in contact with it.

The next step seems to have been to install the rubber wires in pipe conduits. These pipes were made so as to screw into metal junction boxes installed wherever the circuit branched or where a light or other fitting was to be installed. It was thought that by installing the wiring in piping it would be protected from seep water. Unfortunately, however, a considerable portion of this pipe was buried in the concrete, and in spite of all that could be done it seemed as if seep water would find its way into these conduits and would destroy the insulation and eventually ground the system. After several years' experience, therefore, this system was abandoned.

The next step was to abandon the rubber-covered wire entirely and to make use of lead-covered cables. In some cases these cables were attached by insulated hangers to the walls and ceilings so as to be in plain sight, and in other cases attempts were made to bury the lead cable in the concrete. Unfortunately, however, it has been found that seep water destroys the lead coverings of cables even more rapidly than it affects the rubber insulation, so wherever lead cables are buried in concrete, trouble is soon experienced with them, and even where they are exposed to view care must be taken to protect them from seep water.

Exposed wiring has the advantage of easy inspection and if the hangers are properly insulated, electric leakage will probably not occur. Unfortunately, this exposed wiring proved disadvantageous in those localities where the discipline of the personnel was not what it should be. Most seacoast forts are located where there is good fishing and the sight of so much lead seems to have proven an irresistible temptation to the would-be fishermen of the garrison who, in attempting to strip off the lead for their sinkers, were not always as careful as they might have been to avoid harm to the rubber insulation under the lead or damage to the copper cores.

To avoid the class of injury just mentioned, as well as other mechanical injuries, the next step was to make use of armored cables attached by hangers to the walls or ceilings. This was the method recommended by a board of officers appointed some eight or ten years ago to give consideration to and submit reports upon the best type of wiring and electrical fittings for fortification use. It is now the standard practice.

On account of the excessive dampness in the old emplacements, considerable leakage occurred at all switches which, at first, were ordinary throw switches. To avoid this source of leakage it soon became customary to provide as few branch circuits as possible, leaving practically the entire lighting system of an emplacement as a single circuit, controlled by a switch on a panel board in the engine room. Here the heat from the engine soon dissipated the dampness and the electrical leakage was, therefore, comparatively small.

This system of having the entire emplacement lighted by a single switch had the great disadvantage that if anything happened to any part of the circuit no part of the battery could be lighted.

The next step, therefore, was to divide up the battery into sections, each lighted by a special circuit and each circuit operated by a special switch on a panel board in the engine room. This gave rise to the panel-board system. With the improvements made in the new batteries in the way of preventing condensation and dampness from other sources, it became possible, and it was much more convenient, to place other panel boards at different portions of the battery Most modern large emplacements have several panel boards.

Wherever the panel board system is introduced, the cable connecting the panel board and the main switchboard in the engine room is not tapped between. At the panel board there is a large switch so that the circuit can be broken there in case it is necessary. At the engine room end, the cable leads off from one of the switches on the main distributing panel, which usually is fused, though occasionally circuit breakers are substituted for the fuses.

The distributing panel boards must, of course, be made so as to withstand the shock and blast of the guns when fired. They must be so located as to be protected from seep water and reduce condensation to the minimum. Condensation can be prevented to a great extent by making the panel boards of comparatively thin slate, and by mounting them so as to be held several inches from the wall by strips of wood or other heat-insulating material. In such a position there can be no conduction of heat from the panel board to the wall and with the air circulating freely both in front and behind the panel, its temperature should remain always practically that of the surrounding air.

In some of the earlier installations, the Artillery battery commanders requested that these panels be placed in boxes so that they could be kept locked and this request was complied with. Since it is very desirable that a person, by a glance at the board, should be able to see whether any particular branch circuit is switched on or off, the front doors of the panel boards first installed were made of glass. Unfortunately, these glass fronts were often broken by the blast of the guns during target practice, and it therefore became customary to substitute for the glass a copper wire netting.

Boxing-in the panel board interfered with the free circulation of air around it, even though the front door was of netting, and consequently there would usually be more or less condensation and slight electrical leakage. To avoid this there were designed tightly closed panel boards with doors which shut into rubber rabbets, thus inclosing the panel board in an air-tight case.

The object of having the panel boards inclosed air-tight is to prevent condensation, but it should be noted that whenever the box is closed the air contains the same percentage of moisture as the air in the emplacement at the time the box is closed. If, thereafter, the temperature should fall, condensation will necessarily take place inside the box, and what is more, when once this has taken place evaporation can not occur until the temperature of the box is raised.

It is the opinion of the author that it should not be necessary to place the panel board in a box at all or to lock it up. With proper care no unauthorized persons should be in the neighborhood of a panel board, and with the proper discipline no unauthorized members of the detachment would ever attempt to throw the switches on the board.

It is believed, therefore, that the most satisfactory form of panel board is an open one. It should be located in a convenient place and be so mounted that there will be practically no condensation.

It should, of course, be unnecessary to state that all the branch circuits of a distributing panel board should be properly fused. Wherever a distributing panel board is used, it is very convenient to have on it a small pilot light, not only for the purpose of lighting the board and making it easier to read the names of the respective switches, but also for indicating whether or not the power is on and is properly connected in the power room. This panel lights should, therefore, be connected into the circuit below the main switch of the panel board so as to be in operation whether the main switch is thrown in or out.

The cables feeding these distributing panel boards are usually quite large and should be used for this purpose and no other. They should not be tapped between the panel board and the switchboard in the power room. In a properly designed battery it should be possible to lay the main line cables of this character in conduits and if this be done, the cables need not be armored.

This same thing is true of the cables feeding the hoists. Ordinarily, the projectile and powder hoists of any emplacement are very close together and the current feeding the hoists is large enough to justify a cable being used for this purpose and this purpose only. This cable should lead back from the neighborhood of the hoist to the switchboard in the power room, preferably through a conduit. If a conduit is available, it is not necessary that these large cables should be armored. In the hoist room this cable may go directly to the controller of the hoist if there be but one, or if there is more than one hoist, to a small branch panel board conveniently located with respect to the different hoists.

As was stated, it is now the standard practice that emplacement wiring should be exposed, the cable being lead covered and armored and attached to the ceilings or walls by hangers. This is strictly true of the branch circuits leading from the panel boards to the lights themselves. Ordinarily, the panel board is located either in one of the principal galleries or corridors or in one of the principal rooms of the emplacement, and the wires leading from this panel board to the other rooms pass along the ceiling of galleries and corridors. Where they pass through walls, they do so through short pieces of pipe, either iron or terra cotta, installed when the walls are built. The 2-foot air passages needed for ventilation and dryness frequently form very convenient routes for these cables, since there is usually not much passing of people through them, and consequently the cables installed there are fairly free from the danger of accidental mechanical injuries.

The main large cables leading from the panel boards back to the power room are usually installed in conduits put in place when the emplacement is built. Usually these conduit lines are installed under the floors and lead from the power room through the main corridors or galleries. At intervals, manholes or handholes are placed and these are, of course, necessary wherever the conduit line branches.

In one battery the experiment was tried with considerable success of installing the conduit lines in the ceiling just above the reinforcing bars instead of under the floor. The conduits used were of fiber duct and were laid a single tier deep. At intervals, handholes were left which were closed by hinged doors that could be swung down when access was necessary.

The number of conduits necessary in emplacements is usually not large. One conduit is needed, of course, for each light panel board and one for each hoist panel board. One should lead to the ordnance motor generator room if there be one, and one also to the gun well of large guns. Other conduits are desirable for bringing fire-control wires into the battery and these conduit lines must, of course, be connected with the interbattery system of conduits.

Duct System.

In the earlier fortifications, the emplacement electric systems were usually local, there being a separate plant for each large emplacement and it being rather unusual for this plant to be used for other purposes. Where it became necessary to use it for other purposes, the connecting cables or wires were usually strung in the air on poles.

Hanging the power cables on poles, of course, made them quite vulnerable, and the next step was to use lead-covered cables and simply bury them in the ground.

As long as these buried lead-covered cables were not interfered with they worked all right, but unfortunately it became frequently necessary to lay other cables in the vicinity or to dig trenches for water pipes, sewers, etc., and in digging into the ground the lead-covered cables were often injured. Consequently, it became customary wherever cables were buried in the ground, to use armored cables exclusively.

Later on, in connection principally with fire-control communication, the system of installing fiber or terra-cotta ducts was introduced and the number of such conduits was always made sufficient to provide for the battery and other power and lighting cables.

Duct systems are provided for fire-control cables, for power cables, and for the cables required in submarine mines, but as the requirements of the last mentioned are usually somewhat peculiar they will not be further referred to in this place.

Apparently the best form of duct system now used consists of terra-cotta multiple-duct tiles embedded in concrete. The trench is first dug, a foundation of a few inches of concrete is laid on the bottom, the tiles are then put into place and are afterwards surrounded on the sides and covered on the top with concrete.

Another and alternative form of duct system which has proved very satisfactory, especially in certain of our tropical possessions where the breakage of tiles in transit rendered the tile system very expensive, is a fiber-duct system. These fiber ducts can be purchased in the market of different diameters and usually in 5 or 6 foot lengths. They are laid in concrete in much the same way as the tile ducts and usually in such a manner that the different ducts break joints.

Ordinarily, it is customary to install but one cable in each duct, although if the cables are small and are available so that they can be drawn in at the same time, it is possible to lay two or three small cables in one duct.

For convenience in the installation of these cables, manholes are required. In general, the cables are furnished in thousand-foot lengths. It usually is considered necessary to have manholes where the different cables join, and as it is somewhat inconvenient to haul in a full thousand feet at a time, it is usual to build about two additional manholes in each thousand feet of duct line. This places the manholes in a line of ducts about 325 feet apart. Additional manholes must also be provided wherever two conduit lines intersect or where a conduit line branches.

In cases where the power cables carry only direct currents and where the voltage does not exceed 250, it is permissible to lay power cables and telephone cables in the same line of conduits, but of course in different ducts.

Where, however, the power system is alternating current and especially where the voltage carried is high, power cables should have conduit lines different from the lines used for telephone communication. Not only is this due to the danger of crosses where high-tension power cables and telephone communication cables pass through the same manholes, but because it is found that where alternating-current cables are laid parallel and fairly close to telephone cables, the alternations of current cause a ringing sound in the telephone which interferes with the hearing.

The installation of conduits has now reached a stage where the shape of the manholes has become standardized and drawings of the standard manholes should be examined and studied.

Between manholes a conduit line should be made as straight as possible. In general, it should be graded so as to drain to one or the other of the manholes, and great care should be taken to be certain that there are in a conduit line no depressions between manholes in which water may accumulate.

Cables which are to be inserted in the conduit system should always have a waterproof covering of lead, even if they are not armored. All joints should be made at manholes only, should be well and carefully made and waterproofed, the lead sheaths of the two cables being connected by a lead sleeve carefully soldered to both sheaths.

If properly installed, such a system will not be injured should water get into the manholes or conduits. Of course, it is better that the water be kept out if possible, and wherever drainage is available the manholes should be properly drained. In many localities where conduit installations are placed, however, the bottoms of the manholes and the conduits themselves will not infrequently lie below the ground-water level and it is inevitable that in time these conduits will fill with water. If this happens no damage should occur to the cables if they are properly waterproofed and whenever any work is to be done on the cables it is a simple matter to pump out the manholes.

There have, however, been cases where the ground water seeping into the conduit system has in time pitted the lead covering of the cables and of course leaks and grounds have resulted. This occurred in the defenses of Honolulu just westward of the mountain known as Diamond Head. Immediately to the westward of this mountain there was originally a large swamp or flat. This had been reclaimed into a park and the flow of water concentrated in a well-defined stream over which there were a number of bridges. The lowland was quite extensive and when it became necessary to lay conduits, economy pointed out that the conduit system should pass through the park rather than make a very long detour around it.

At certain seasons of the year the level of ground water rises up to within a few inches of the surface of the ground, and of course the manholes and conduits in this part of the system are flooded and remain full of water. For a number of months the system worked all right, then grounds began to appear and soon became worse and more numerous. An investigation was made and the cables were found to be badly pitted, apparently due to the action of the ground water. This ground water was essentially swamp water and contained much vegetation in solution, and some of these vegetable salts had evidently acted upon the cables. It therefore became necessary to re-lay a portion of the conduit line on a long detour in the higher ground around the original swamp.

Fittings.

When it first became necessary to wire emplacements for lighting, the fittings selected were those used in commercial life. These were the usual types of porcelain lamp bases, switch bases, and so on. On account of the dampness always present in these older emplacements there was much electrical leakage from these fittings, and it soon became evident that special fittings would have to be used.

The next step was to use metal boxes for all fittings, the wires being carried into them through pipes screwed into the boxes. The top of the box, where it was a mere junction box, was made solid. Where lamps or switches were to be installed the tops were specially prepared for or made a part of these fixtures. These tops were screwed on tight, and the rabbets into which they fitted were usually lined with rubber so that the joints would be what was considered air-tight.

In the early days there was no standard design for these boxes, and the selection of the type to be used in any emplacement was left to the district officer. He usually had to choose a type that happened to be available in the locality. The earlier boxes were screwed to the walls or ceilings through holes in the base, and it was attempted to make these openings water-tight. However, whenever the guns were fired the shock was distributed through the concrete of the emplacement, causing a vibration, and quite frequently this vibration would loosen the screws or would destroy the waterproofing around them. Water would begin to seep into the boxes, especially where their bases were screwed to the ceiling. Once in the box, of course, the water was apt to cause grounds or short circuits.

It was evident, therefore, that another form of box was necessary, and one was designed that is fastened to the ceiling or walls by exterior lugs. Some of the boxes are, of course, used for making joints in the circuits. In all such cases these joints should be thoroughly waterproofed, using almost the same care as is done in joining electric cables to be installed in conduits, where it is supposed they may occasionally be covered with water.

Some of the boxes are, of course, used for switches. Many forms of switches have been tried, the most common form being that manufactured by the General Electric Co. and shown in their catalogue. As long as this switch is always turned in the same direction this type works satisfactorily, and it has a ratchet arrangement provided with a spring to prevent it being turned in the wrong direction. With intelligent handling no difficulty should have been experienced with this form, but unfortunately the type of enlisted man frequently met with can not be trusted with the handling of delicate switches. They seem to think that if you turn the switch in one direction to turn on the light, you would naturally reverse the direction to turn it off. The fact that the switch seemed to work hard in the reverse direction did not deter them, and they would frequently use sufficient force to break it. It therefore became necessary to use specially designed switches. It should be noted that all switches when inclosed in a box should have on the outside easily legible marks to show when the switch is on and when it is off. This is desirable also with snap switches.

Where the box is used as a lamp base not only must there be the socket for screwing in the lamp (and this should preferably be of the spring type), but there must also be a screw thread for screwing on the protecting globe. This goes outside of and over the lamp and should screw down water-tight. Outside of this globe there is usually provided a basket metal work guard for protecting the globe and the bulb inside from mechanical injuries.

Lamps.

The lamp ordinarily used is the standard carbon filament 16 candlepower lamp designed for a voltage of about 110 to 112. Occasionally, however, 32-candlepower lamps are used, and in a few cases even larger ones have been provided. In range stations, dormitories, casemates, etc., which are ordinarily situated so far away from the nearest large gun as to be free from blast effects, the ordinary carbon filament used in commercial life is satisfactory, and even the Mazda and other sensitive filament lamps can be used. Such sensitive filament lamps have the advantage of providing more light for the same expenditure of current than the carbon filament.

But in gun emplacements, especially on or in close proximity to the loading platform, the blast effect and the vibration or shock are usually so great that nothing except carbon filaments will stand, and these ordinarily have to be of special manufacture—that is, their carbon filaments have to be unanchored, since it is found that anchored filaments are broken too frequently.

Incidentally also it has been found that in such locations the ordinary fixed lamp socket is not suitable since the shock transmitted through it has a tendency to break even the unanchored carbon filaments. Spring sockets should therefore be used. Not only have these spring sockets been found to greatly diminish the breakage of the filaments, but lamps screwed into them do not have the tendency to gradually unscrew and get loose, as has been found to be true of the ordinary sockets.

It having been found that there was an excessive tendency for fortification lamps to disappear from batteries and other similar places, it was thought to be necessary to have the lamps marked specially. In recent years fortification lamps have usually been bought under specifications requiring that bulbs should have etched on them the letters "U. S. E. D." or something similar.

The subject of the best designs for electric fittings to be used around emplacements has been considered from time to time by various boards, and some three or four years ago standard forms of fittings were adopted, and the main Engineer depot at Washington Barracks was intrusted with their manufacture and purchase. It was at that time ordered that all constructing engineers who might have need of such fittings should submit requisitions to be filled by the Engineer depot.

The details of the standard fittings have been very carefully thought out, and there are now available forms of fittings which are suitable for practicably every use that can arise in fortification structures. Drawings of these fittings and perhaps samples will doubtless be made available to officers who need them.

In dormitories, casemates, fire-control stations, and other buildings isolated from batteries these special fittings are not required, and such buildings can be wired very much in the same general way as buildings in civil life, this wiring usually being governed by what are called underwriters' rules.

DIFFERENT USES OF ELECTRICITY.

At the present time electricity is used in fortification work in the following ways:

First. For searchlights.

Second. For illuminating emplacements of all kinds, range stations, etc.

Third. For lighting the range scales on the guns and on the range finding instruments and for lighting the wires of observing telescopes.

Fourth. For operating hoists.

Fifth. For gun maneuvering apparatus.

Sixth. For firing guns from a distance.

Seventh. For telephone communication.

Eighth. For operating range-indicating apparatus.

Ninth. For furnishing power for telautographs.

Tenth. In connection with submarine mines.

Electric Power for Searchlights.

The power for operating a searchlight can be obtained from a central plant, from a local battery plant, or, where the searchlight is isolated, from a special searchlight plant. Where the searchlight is mounted in a fixed location, and this location is within easy reach of a connection with a central plant, it is not infrequent to connect the searchlight with the central plant, but since this connection may be cut off at a critical moment, it is customary to provide the searchlight with a special plant of its own as a reserve. Similarly, when a searchlight is located not too far from a battery, connection with the electric system of the battery is frequently made. In such a case, also, a reserve plant is needed. The standard searchlight plant for a 60-inch searchlight is a 25-kilowatt generator.

The tendency in the recent past, however, has been to mount two searchlights in the neighborhood of each other and so close together that either can be used to illuminate the same field, and yet not so close together as to make both subject to destruction if a shell should strike or explode near one. Each searchlight is given its independent power plant, but in order to make the system more flexible, each searchlight is ordinarily connected with or is connectible with the power plant of the other.

Searchlights require direct current, so when a connection is made with an alternating current central plant or another source of alternating-current power, it is necessary to provide a motor generator at or near the searchlight to furnish the direct current necessary for the light. Although a slightly lower voltage might be used with searchlights, it is customary, in order to keep to the general standard, to run the local searchlight plants at about 110 to 115 volts, the standard for lighting plants.

In connection with antiaircraft operations during the recent war there has been a great development in portable searchlights, and in portable powerplants for them. Portable searchlights were, of course, intended primarily for antiaircraft work; but with the addition of distant control mechanism, and in certain cases of some method of raising the light to a height, these searchlights will probably be quite serviceable for fortification use, as will also the portable power plants.

Two separate types of automobile portable power plants have been secured, one consisting of what is practically the standard 25-kilowatt generating set, mounted on a large automobile truck, with a separate engine for operating the truck; and the other a generating set carried on a truck, the engine of which is so designed as to be used either for propelling the truck or for operating the generator.

In addition, a portable searchlight plant has been designed for operation on railroads. The plant consists of two cars, one a searchlight car containing the searchlight plant, and the mechanism for elevating it to a height of 40 feet or so, and the other a car containing a standard 25-kilowatt set to furnish power.

Use of Electricity for Lighting Emplacements, etc.

As far as the use of electricity for lighting emplacements, range stations, etc., is concerned, the conditions are closely analogous to those found in civil life, except for the necessity of protection from hostile fire, and of avoiding the difficulties due to dampness and the blast effect from the guns.

In the earliest emplacement installations it was customary to have all, or nearly all, of the lights of the emplacement operated by a single switch in the power room. Only occasional use was made of special branch circuits, as in lighting a magazine or some other room not in frequent use. It is needless to say that with such a system, if you wanted to light a single room, or a single part of a room, it was necessary to light the entire battery. This system had the further great disadvantage that a single short circuit would make the entire battery dark.

The main reason for this character of installation was the extreme dampness of the old emplacements which caused the switches to be almost always a source of electric leakage. We therefore find that the earlier boards in their reports discouraged the use of branch circuits. However, with the armored cable now furnished for electric installation, with the standard type of switches now in use, and with the arrangements for ventilation and prevention of dampness which have been installed in the more modern batteries, there is no longer any reason why switches should be a source of trouble and why it should not be permissible to divide up the lights into as many separate circuits as may be convenient. Lately, therefore, the custom has been introduced of dividing an emplacement up into a number of different circuits, one for the loading platform lights, one for the magazine lights, one for storeroom lights, one for air space lights, and so on. As a rule, these branch circuits contain from seven to twelve 16-candlepower lamps each.

At first the plan was tried of having these separate circuits operated by ordinary switches placed around the walls, but the difficulty of keeping these numerous switches in order caused them to be abandoned and for them were substituted distributing panel boards conveniently located. Each panel board is connected with the main switchboard in the power room by a cable which is not tapped between the two points. In small batteries, only one panel board is used; in larger ones, two, and sometimes four. In a few cases panels with as many as 16 or 18 branch circuits have been used, but a better practice would seem to be to use more panel boards, with not more than 10 or 12 branches on each.

The greatest difficulty that has been met with in properly lighting the loading platforms of heavy direct fire gun emplacements is the blast damage done in such places by the guns when discharged.

In order that the operation of loading the gun may be done rapidly, it is essential that the loading platform be properly illuminated, and yet this illumination must not be so strong as to make the location of the emplacement visible to the enemy by the glare.

This illumination has been attempted in two ways; the first being by lights around the walls immediately under the overhang. The lamps installed there must, of course, be very strong and have unanchored filaments. They must be held in place by spring sockets and protected by heavy glass globes mounted in metal basketwork frames. Incidentally, also, in order that the glare from any of these lights may not interfere with the man at the sighting telescope as the gun is pointed in different directions, each one of these lamps must have its own independent key so it can be turned on or off at will.

The other method of illuminating the loading platforms is by the so-called "footlights" hung from the handrailing at the rear of the platform and provided with screens so adjusted as to prevent the light from shining over the parapet.

In the Panama and similar one-story emplacements where the loading platform is surrounded by sand slopes the footlights are attached to posts set in the ground. All footlights should be keyed.

In addition to the lights mentioned above, should anything go wrong about the gun carriage, some form of portable light is very useful. Consequently two standard Engineer Department keyed sockets for the attachment of portable lights are installed on the front walls of a gun emplacement, one on either side of the capital of the emplacement. It is intended that whenever an emplacement is in use at night the portable lamps shall be brought out from the storehouse and the ends of the cables be attached to the corresponding sockets, the cables being coiled up until the lamps are needed.

Another and very convenient place for portable lights is on the gun carriage itself. When the early emplacements were built, it was not considered necessary to carry electric-light wires into the gun wells, and no arrangements for doing this were made. Consequently when it became necessary to establish lights on the gun carriages great difficulty was met with in getting the cables in. In some cases long holes from the gun well to some neighboring portion of the emplacement had to be cut at great expense. In the more recent batteries, however, arrangements for carrying cables, and for that matter speaking tubes, too, to the gun wells have been provided as will be noted by an examination of the detailed drawings of the Panama emplacements.

With small, rapid-fire guns which are mounted in barbette and under conditions, therefore, such that the illumination of the loading platform is not possible in action, sockets for attaching portable lamps are fastened to the gun pedestals and lighting cables are led to them.

The blast of mortars is so very great as frequently to destroy even the best form of wall electric light yet developed. Consequently these wall lights can not be relied upon for the illumination of mortar pits in action, although they are extremely serviceable for drill purposes. Occasionally they are not destroyed when the mortars are fired. It having become evident that some other method of lighting the mortar pits was necessary, a method by means of reflecting cones was developed by the writer at Fort Monroe for the maneuvers of 1905. These cones were attached about 20 feet above the ground to posts planted in rear of the mortar pits. The cones were composed of galvanized iron, painted white on the inside, and were so adjusted in direction that the axes of the cones prolonged passed about through the center of the floor of the pits. At the inside of the upper end of the cone was inserted a base to which was attached three 32-candlepower electric lights. It was found by experiment that, except when the mortars were turned around so as practically to face directly toward the cones, the electric lights in them would withstand the blast, and that the illumination given by two cones is more than ample.

In the more recently constructed mortar batteries the cone lights have been attached to brackets on top of and near the rear of the side walls of the mortar pits. (See Plate XXIX.)

One of the rooms in an emplacement which has to be particularly well lighted is the plotting room. The plotting is usually done with pencil, and therefore good illumination is necessary. Furthermore, a number of men are employed around the plotting board, and the illumination must be such as to avoid shadows as much as possible. The standard method of illuminating the plotting board is by four 32-candlepower lamps attached to the ceiling directly over it and placed on the corners of a square about 3½ or 4 feet on the side. Additional lights have to be located where they will give the best illumination on the various correction boards, etc. Such lights should preferably be hooded. There must also be other lights for the general illumination of the room.

The illumination of the power room must be so designed as to give ample light at the switchboard and on critical parts of the engine. Portable lights, also, are frequently of great assistance.

As an illustration of the general character of the electric-lighting system installed in modern batteries, the following is quoted from the report of the designing engineer in submitting to the Chief of Engineers the plans for one of the modern large Panama batteries:

> The conditions are such that artificial illumination will be required, even by day, in the magazines, galleries, and rooms of these batteries. The artificial lighting is to be done ordinarily by electricity, and in case electricity temporarily fails, then by the standard emergency lanterns. Recesses for these emergency lanterns are shown on the drawings, around the loading platforms, in the truck corridors, the shell rooms, and opposite the magazine doors, but as the supply of these reserve lanterns will always be limited their use has generally been restricted to these locations. These lanterns are not sufficiently powerful to be of use for plotting purposes, and the emergency illumination by them of the other parts of the battery would not appear to be desirable.
>
> In general, each group of from 7 to 12 lights is formed into a separate circuit, fed by a cable leading back untouched to a distributing panel, of which there are 4 located in convenient places in the rear gallery. On these distributing panels are to be located the operating switches for the branch circuits, and in general they will be the only switches on those branch circuits; but in the plotting rooms and officers' rooms and in a few other special locations wall switches and specially keyed lights are considered necessary. The distributing panel is to be connected through a switch to the main cable extending into the power room and should have a small pilot lamp set in a keyed socket. The figures on the drawings of the distributing panels show the number of branch circuits now estimated as required and the extra spare connections considered necessary for future growth.
>
> Two general methods of artificially illuminating the loading platforms are shown—one a line of footlights set around the rear of the platform, as directed in mimeograph 93, and the other a line of lights located under the overhang of the front parapet wall. All these lights should be provided with keyed boxes, so that any light which may temporarily interfere with the view of the men on the sighting platforms of the guns, or of the officers in the battery commander's stations, may be darkened.
>
> Sockets for portables are shown in the battery commander's stations, around the wall in front of the gun well, and around the steps in the rear of the gun well.
>
> The power, lighting, and fire-control wires to the gun carriages are to be connected through the Ordnance Department terminal boxes set in niches in the rear walls of the gun wells. All these wires are to be routed from the plotting room through the tunnels and passageways.
>
> The electric-light and power wiring shown is to be generally of the exposed type attached to the walls or ceilings, except when passing through walls. In passing through walls the wires are to go through short conduit pipes to be inserted in the walls when built.
>
> The cables and fixtures used are to be of the Engineer Department standard type.
>
> The positions of lights and distributing panels and the routing of electric cables as shown on the drawings are to be considered to some extent as diagrammatic, the details being left to the constructing officer.
>
> For the convenience of handling fire-control wires and power cables, a series of electric conduits has been provided in these batteries. The main conduit system consists of a line of conduits laid under the floor of the rear gallery and extending from end to end of the gallery. From this main line, branch conduits communicate

with each plotting room, with the power room, and with the lower level of the island, the latter conduits being laid under the stairs of the entrance galleries. The conduit lines extend to the extreme right end of the rear gallery, whence they may be extended to any fire-control stations which may be constructed. The number of ducts which it is considered necessary to provide in each portion of this conduit system is noted on the plans.

From the conduit manholes in rear of each plotting room branch conduits are to extend, two to the wiring recesses of the plotting room, one to the wall of the rear gallery (for the lighting main), and one to the indicating apparatus manhole for the power mains leading to the gun carriage.

In the operating room of casemates, the lights must be so distributed to give ample illumination on the various switchboards, and portable lights conveniently arranged for seeing behind the boards are frequently of great assistance.

The illumination of observation stations requires considerable thought and care. For an observer to see through a telescope at night, it is usually necessary that everything around him should be as dark as possible. Furthermore, any glare or gleam coming from a range station may attract the attention of the enemy to its existence, and may therefore attract the enemy's fire and endanger the station. Both of these requirements therefore, would point to there being no lights in a range station. However, it is frequently desirable, especially in a battery commander's or fire commander's station, to consult charts or maps or other papers. Wherever illumination for this purpose is necessary it should be provided by carefully hooded lights in the extreme back part of the station, the lights being so located, hooded, and screened that no glare can reach the observer or can show through the observation openings.

A somewhat perplexing problem that frequently arises is the illumination of outlying observation stations, small dormitories, and small rapid fire batteries, when these structures are located far away from other portions of the defenses. These observation stations and dormitories will probably be but infrequently used at night during peace time, and as has just been stated, in actual war time but little light, if any, should be permitted in the observation stations. Consequently, it would appear almost as if it were a useless expense to provide electric lighting connections to such stations or dormitories. On the other hand, of course, fire-control cables must be carried to the stations and it would cost but little more to install a small power cable at the same time. It is the opinion of the author, however, that unless there are quite a number of these stations in fairly close proximity to one another, it is an unnecessary expense to provide electric lighting. For ordinary illumination, oil lamps can be used and the illumination of range scales and telescope cross hairs can be done by dry batteries.

The same thing, it is believed, is true of most rapid fire batteries. These guns are necessarily mounted in barbette and no light can be permitted on the platforms when in use at night. The ammunition usually comes fixed and little light would appear to be needed in the magazines. Such as is needed could be provided by reserve lanterns.

Unless, therefore, such batteries are grouped together, it is believed that they all might well be left without electric light connections. If there are, however, several batteries grouped together it may be worth while to install for lighting the group a small detached electric plant, but it is evident that for such purpose the standard 25 kw. sets are too large. For small groups, possibly 5 kw. sets might be provided. Up to the present, however, no standard set of this size has been adopted by the Engineer department.

Lighting Range Scales and the Cross Hairs of Telescopes.

The small lights used to illuminate the range scales of rapid-fire guns and position-finding instruments, the cross hairs of range-finding telescopes, and the sighting telescopes on gun carriages are from about one-half a candlepower to 2 candlepower. These lamps are furnished by the Ordnance Department and at first the power was provided by a dry battery. However, as the dry batteries furnished for this purpose proved to be somewhat unsatisfactory a new arrangement was adopted. The Ordnance Department now furnishes with the lamps a suitable rheostat. Connection is made with the ordinary lighting mains furnished by the Engineer Department and carrying about 110 volts. This voltage is cut down by the rheostat to the voltage necessary for the lamps. Occasionally also, the expedient is adopted of placing several of these small voltage lamps in series across a 110 volt circuit.

Power for Ammunition Hoists.

The use of electric power for operating motors is exceedingly common in commercial life and the use of such motors for operating hoists in fortifications has nothing unusual about it. The standard form of electric hoist is operated by an ordinary shunt motor, there being a clutch so that the hoist itself can be thrown in or out of gear. The motors are started when the clutch is out and the hoist itself not connected. When the motor is running full speed the clutch is thrown in and the hoist starts to move. After it has attained full speed it is ready to take up ammunition.

As in all motors, in order to prevent a sudden rush of current on starting there is a starting rheostat, the resistance of which is gradually cut out as the motor gains speed. This rheostat and the switches connected with it are operated by a form of controller, in general not unlike that used on street cars. The motor is started by turning the controller handle to the first notch; as the motor gains speed the handle is moved from notch to notch, and when nearly at full speed the handle is thrown all the way around, cutting out all the resistance of the starting rheostat. This handle is so connected with the brushes that if the circuit be at any time broken the connection between the handle and the brushes is broken and a spring returns the brushes to the starting position. In order to start the motor again, it is necessary to push the handle all the way back and pick up the brushes again.

This arrangement is utilized in a very ingenious way to prevent accidents with the ammunition hoists. The controller operating a hoist is usually located in the hoist room on the lower story. The projectiles are raised and are rolled out by the hoist on a delivery table on the loading platform. It is, of course, possible that there may be a delay on the loading platform and the projectiles may not be taken away as fast as they are carried up. If the delivery table be full and an attempt is made by the hoist to place on the table another projectile for which there is no room, there is danger that it may fall down through the hoist opening and do considerable damage. To avoid this, the circuit passing through the automatic clutch that holds the brushes to the controller handle passes also through a small switch placed on the loading platform level alongside the delivery table. If the attendant at the delivery table sees that there is any tendency for the table to become overloaded he opens the small switch, thus releasing the clutch that holds the brushes to the controller handle. The spring throws the brushes back to the starting position and the hoist instantaneously stops.

In connection with the use of electricity for operating the hoist motors there is one point that should be noted, attention having been called to it by a peculiar occurrence at Fort Hamilton some years ago. As has been described, projectiles are brought to the receiving table of a hoist by a trolley running on a trolley rail attached to the ceiling. When over the receiving table, the pulley block is slackened off slightly and the projectile is lowered to the table. The receiving table is connected with the frame of the hoist upon which is mounted the operating motor. Now it so happened that at Fort Hamilton the negative wire of the motor was grounded to the frame of the hoist and therefore was electrically connected with the metal of the receiving table. Incidentally, the trolley rail passed close to and was in metallic contact with a lamp socket in the ceiling in which the positive wire happened to be grounded. Theoretically, according to the knowledge of the time, the grounding of one side of the electric system in one part of an emplacement and of the other side at another place should have made the electric current complete and should have been at once indicated in the power room by the blowing of a fuse or the opening of a circuit breaker.

It was at that time supposed that concrete in mass was a good conductor of electricity and that a piece of bare metal in contact with the concrete was effectively grounded. This has been found not to be true unless the concrete is saturated with water. Dry concrete partakes largely of the nature of a conglomerated limestone, or marble which is but a form of limestone, and is such a poor conductor that it is frequently chosen as a material of which to make switchboards. In fact, as is noted in the chapter on dryness and condensation, dry concrete is not only a poor conductor of electricity but is also a poor conductor of heat.

At Fort Hamilton, therefore, we had a case of the trolley rail being grounded on one side of an electric circuit and of the hoist frame and receiving table being grounded to the other side. While in this condition a projectile was brought to the receiving table hanging from the trolley. As it approached the table one of the detachment with his hand on the projectile touched the table with the other hand and received a shock. A few seconds later the point of the projectile swung around so as to touch one of the sides of the receiving table making a distinct spark, and what is more, the projectile after touching the side of the table swung away and hung so as to leave but a short interval between the projectile and the receiving table and there was thus formed between the two a distinct iron arc similar to the carbon arc which is used in the electric arc light.

Fortunately, no damage was done, but it should be noted that at that time it was customary to use the same hoist not only for raising projectiles but for raising powder. Had this arc occurred in the neighborhood of powder there would have been great danger that the powder on the receiving table might have been set on fire much in the same manner as had actually occurred a short while before in the turret of one of the battleships. When this sparking occurred, the cause was not known, but an investigation showed the facts to be about as I have stated.

The remedy is exceedingly simple—to bond all sections of the trolley rail and of the hoist together. Had this bonding been in place, as soon as the grounds occurred, one on the positive and one on the negative side of the electric system, a short circuit would have been formed through the metal connections, and either a fuse would at once have been burned or a circuit breaker on the switchboard would have been thrown and attention would have been called to the occurrence.

Power for Maneuvering Gun Carriages.

The installation of electric apparatus for maneuvering gun carriages was somewhat delayed due to the fact that the gun carriage and everything connected with it is manufactured by the Ordnance Department, whereas the electric power comes from the Engineer Department. Formerly there was a lack of coordination between the two departments which has happily been corrected since.

The Ordnance Department decided to install motors on its large gun carriages for traversing, for operating the elevating mechanism, and for retracting the guns.

In connection with the traversing it is necessary that the gun should be kept pointed on the target as the latter moves, and as the target may move across the field of fire of the gun with an infinite variety of speeds, the motor operating the traversing mechanism must be capable of very delicate adjustments in speed. A special motor generator is installed in a special room of the emplacement convenient to the gun-well. The motor generator receives power from the Engineer Department cables and furnishes power to the traversing motor which is of such a character as to permit an adjustment to any desired speed.

The earliest traversing motors did not give complete satisfaction and the Ordnance Department, for a while at least, abandoned the idea of installing them, leaving the traversing gear to be worked by hand. Whether or not it is the intention to install traversing motors on the new gun carriages is not known, but it is believed that it should be done.

The other two uses of power on gun carriages, that is, elevating and retracting, are performed by the same motor and no such delicate adjustment in speed is necessary as in traversing. This single motor is so arranged that it can be thrown in gear at will either with the elevating mechanism or with the retracting mechanism.

Firing Circuits.

The use of electricty for firing guns has long been considered as desirable and it was at one time intended to use the regular source of power for this purpose. Later, however, this idea was abandoned as being too dangerous. Where electric firing is to be used it is done by special batteries or magneto machines, the circuits being kept entirely separate from those used for lighting or power purposes, even to the extent of being carried in separate conduits. This is largely a matter for the Ordnance Department, the only duty of the Engineer Department being to install the necessary conduits.

Power for Telephones.

Telephones, telephone wires, and all the incidental accessories are furnished by the Signal Corps. Prior to a few years ago they were likewise installed by the Signal Corps, the work as a rule being done by civilian electricians and hired labor. A little later skilled noncommissioned officers of the Signal Corps were employed to supervise this work.

A few years ago, however, while the Signal Corps still retained the control of the purchase and issue of all telephone material, the actual wiring was left to be done in garrisoned posts under the supervision of the Artillery Engineers, and in new fortifications by the Engineer Department.

As a source of electric power, the Signal Corps has sometimes furnished independent generators, sometimes motor generators which receive their power from Engineer department cables. and sometimes storage batteries which are charged from the Engineer department power lines. No further reference will, therefore, be made to this subject here.

Power for Range Indicator Apparatus.

Electricity has occasionally been used for operating the apparatus for indicating to the men at the guns the range of the target or the other data needed for laying the guns. This being a matter closely connected with fire control, will be discussed in the chapter on that subject.

Power for Telautographs.

A telautograph is an appliance which by electrical means repeats at a distance a supposed facsimile of what is being written on the transmitting telautograph. That is, as a man with a telautograph pencil writes his name on the receiving telautograph, his autograph is repeated at a distance, so as to be almost exactly like the original. This apparatus can, therefore, theoretically be used for the rapid transmission of written data.

The only attempt that was ever made to use telautographs in fortification service was as a substitute for or as a supplement to telephone transmission of fire-control data. The subject will, therefore, be discussed principally in the chapter on fire control.

Both the receiving and transmitting telautographs had to be furnished with direct current at approximately the same voltage. In the initial experiments the telautographs had been connected with perfectly regular sources of power and worked fairly well, but when they were introduced into fortification service and were connected with the fortification electric systems they failed to work. It was not until the experiment was tried of connecting the telautographs to storage batteries, used for the time being for no other purpose than furnishing power for them, that they could be made to work satisfactorily. For this and other reasons which will be noted in the chapter on fire control, the use of the telautographs was abandoned, so that the subject of power for them is of historical interest only.

Power for Submarine Mining.

The power needed in the operation of the submarine mining system is usually obtained from a special generator installed by the Artillery. In connection with the generator they install also a storage battery charged from it, so the Engineer department is not concerned in this use of electric power.

Personnel.

When the electric plants were first introduced in emplacements, not only were they installed by the Engineer department, but they were cared for and operated by civilian employees of that department working directly under the orders of the district engineer officers, but of course operating the plants when directed by the Artillery commanders. In a few places, such as during the maneuvers of 1903 at Portland, Me., the attempt was made to operate the electric plants by a detachment of Engineer soldiers working under an Engineer officer.

This arrangement of having electric plants operated by the Engineer department was not satisfactory to the Artillery, and at about the time the torpedo system was turned over to the Artillery the electric plants were turned over also. An electrical school for the education of Artillery soldiers and noncommisioned officers was opened at Fort Monroe, and these men when sufficiently instructed were placed in charge of the electrical plants.

In Artillery districts there is an Artillery district engineer on the staff of the Artillery district commander. In each coast defense there is a coast defense Artillery engineer, and at each large post there is a post Artillery engineer. These Artillery engineers are in command of all the electrical sergeants, firemen, privates, etc. detailed in charge of the electric plants.

CHAPTER XII.

FIRE CONTROL.

In the lecture on this subject in the original notes, the matter was gone into quite extensively, but since it is probable that the experience of the recent war will soon be reflected in radical changes in the fire-control system the matter will be but briefly touched on in this chapter.

The term "fire control" is used with two separate and independent meanings; first, the assignment to each particular gun of its particular target and the regulation of the rapidity of fire at this target; and second, the communication to the detachment around the gun of the exact location of its particular target in such a manner as to insure that the gun will be fired with such azimuth and elevation as to secure a hit on the particular portion of the particular target assigned. The first of these two operations might better be called "fire regulation" and the second, "position finding."

FIRE REGULATION.

In the chapter on gun batteries and emplacements it was stated that a "battery," as the word is used in reference to seacoast artillery, ordinarily includes from two to four emplacements, though occasionally one large gun emplacement may by itself constitute a battery. The command of such a battery is appropriate to the rank of captain.

The concerted action necessary for success in all military affairs requires that the different batteries in any one harbor or portion of a harbor should not be allowed to do their fighting independently, but should be under the command and control of higher officers. Consequently, it has become customary to combine several battery commands into a higher command called a "fire command," appropriate to the rank of major.

In general, the different batteries composing a fire command would be of guns of the same general caliber and covering in general the same field of fire. That is, in a large fort or collection of forts, the large caliber guns would be divided into one or more fire commands, the medium caliber guns would form other fire commands, and the smaller rapid fire guns still others. The command of submarine mining matters and of the smaller guns detailed specially to protect the mine field would form another so-called "mine command" assimilated to a fire command.

In the same way that the battery commands are organized into fire commands, the fire commands are organized into a more important command known as a "battle command" under the control of a battle commander normally of the rank of colonel. In most cases a battle command would include practically all of the defenses of a single harbor, but in very large and important harbors such as New York, San Francisco, etc., there might be several independent battle commands all organized into still larger commands known as the "fortress command" under a fortress commander, who would ordinarily be a general officer.

It is, of course, essential that the fortress commander should be kept in close communication by telephone or other means with his battle commanders, the battle commanders with their fire commanders, and the fire commanders with their battery commanders. Similarly there must be communication between a battery commander and the various parts of his battery, his observation stations, his plotting room, etc., and between the observation stations and the plotting room.

In this connection, however, it should be noted that the organization of batteries into fire commands, and fire commands into battle commands is a tactical organization only. For general administrative purposes the organization is somewhat different.

The administrative organization is based upon the seacoast fort, each fort as a rule being treated, as far as administration is concerned, as a separate post. In a few cases, smaller forts which are ungarrisoned or very slightly garrisoned, are treated as subposts. The different forts in any one harbor are usually united into a higher command. Formerly this command was known as a Coast Artillery district, the next superior administrative commander being the commanding general of a military department.

About 8 or 10 years ago, however, it was considered desirable to interpose a more general Coast Artillery commander between the Coast Artillery district as then organized and the department commander. The term "Coast Artillery district" was selected for these more general commands and the designation of the command formerly called a "Coast Artillery district" was changed to a "coast defense."

In general, therefore, there is now a coast defense for each harbor, though in the larger harbors such as New York, where there is more than one entrance, there might be a coast defense for each entrance, or one of these entrances even may be divided into more than one coast defense. Thus in New York Harbor there is one coast defense for the eastern entrance and two for the southern, one at the Narrows and one at Sandy Hook.

The coast defenses along one general stretch of coast line are formed into a Coast Artillery district, which is usually commanded by a colonel of Coast Artillery, but sometimes by a brigadier general whose prior service has been in the Coast Artillery. These Coast Artillery district commanders are under the supervision of the department commanders.

This organization and in fact the entire present military organization into territorial military departments would appear to be somewhat anomalous and will, in all probability, be changed before long.

POSITION FINDING.

In target practice with the small arms rifle the soldier aims at the target, making on his sight a vertical correction for the range and a lateral correction for windage, drift, etc. If the range is not known it is guessed at or is determined by the fall of the bullets. The range at which a small arms rifle is fired is usually comparatively small and in general can be determined with sufficient accuracy by the methods just mentioned. However, when the range of the target is known from other means this information should be used and every possible expedient should be made use of that will increase the accuracy of the fire.

The ranges of the old muzzle-loading seacoast guns used during our Civil War and before were comparatively small, the fire of the guns themselves was quite erratic, and consequently, guessing at the range or its determination by actual firing sufficed.

This is, however, no longer true of the guns now mounted in seacoast defense. Many of these have an available range of over 20,000 yards and the next guns to be emplaced will probably have a range of nearly double this or even more. For seacoast firing at such ranges, guessing at the range is out of the question and something more accurate must be attempted.

The simplest method of determining a distance which can not be actually measured is by triangulation, and this is the method used for range finding in seacoast defense. In determining the distance of an object we may do our triangulation either in the horizontal plane or in a vertical plane. Both methods are in actual use and we may, therefore, have a horizontal position-finding service or a vertical position-finding service.

HORIZONTAL POSITION FINDING.

Triangulation in the horizontal plane is based upon the assumption that we have two points whose distance apart is known and that we have at both points instruments which may be used for measuring horizontal angles. The line of known length connecting the two points is called the base line. If the transits at the two ends of the base line are pointed at each other with their verniers set at zero and the telescopes are then pointed at the same distant object and the angles are read, we have the simplest form of triangulation. We have a triangle the length of one side of which is known and two angles of which have been measured, and a few minutes' calculation will give the distance of the object from either or both ends of the base line. Knowing these, the distance and direction of this object from any other known point in the same plane also can be calculated.

If the target whose position is being determined is not moving, the transits may be sighted on it at any convenient time for each, or in fact the same transit may be used, measuring the angle at one end of the base line and then being taken to the other end of the base line and used in measuring that angle. If, however, the target is in motion it is evident that the sighting of both telescopes must be made simultaneously.

If time and good computers were available we might resort in all cases to calculation to determine the distance of the target, but time is of the utmost importance, for the target is moving, and recourse is therefore had to graphics—that is, to the determination of the position of the target by plotting.

The simplest and in fact the original form of the plotting board was rectangular. The base line was drawn to the proper scale near one of the sides of the board. The position of the two ends of the base line, A and B, was plainly marked by points. With the points A and B as centers fairly large circumferences were drawn on the board, and these circumferences had the degrees marked off and numbered, the zero in the case of each circumference being toward the other end of the base line, and the numbering of the graduations increasing in the clockwise direction on one circumference and in the counter-clockwise direction on the other. For use in plotting, pins were inserted in the board at the points A and B and strings were fastened to the pins. The ends of these strings were held by two men called "plotters" to whom, by telegraph or telephone, were communicated as promptly as possible the readings of the two telescopes. Upon receiving the reading of the telescope at one end of the actual base line, the proper plotter would promptly stretch his string so that it passed through the corresponding division of the proper circle. The other plotter would in the same way stretch his string so that it would pass through the division on his side corresponding to the reading of the telescope at his end of the base line. The intersection of the two strings would indicate the position which the object had at the instant the two telescopes were read. This intersection could be marked by a small dot on the paper and the distances of the target from the two base end stations could be read off with the proper scales.

Furthermore, if on the same board the actual position of the gun with reference to the two base end stations was marked, a circle drawn with this point (which we will call G) as the center, and the degrees marked on this circle so as to accord with the degree marks on the azimuth circle of the gun carriage, a string or ruler from G to the dot indicating the position of the target would give the range and direction of the target from the gun.

The somewhat crude and primitive form of plotting board just described was the one actually in use less than 30 years ago. It contained the essential principles of the more modern plotting board, but many necessary refinements have been introduced.

On the earliest plotting board used, three circles were actually drawn, one with each end of the base line as the center, and one with the position of the gun as the center. The zeros of the circles drawn about the ends of the base line were on the line connecting the base ends, one circle was graduated in one direction and one in the other. The zero of the circle about the point of the gun was fixed by actual observation from the direction of the zero of the azimuth circle of the gun.

If we have to calculate the distances of the target from the ends of the base line it is evidently easiest to use the base line as the zero line, but where a position is determined by plotting and not by calculation, nothing is gained by using the base line as the zero line, and there are many advantages if all the angles read and plotted are true azimuths counted from the same zero of azimuth. The Artillery service in this country has selected the south as the zero of azimuths, and all angles are measured from the south around by the west to the north, east, and finally to the south again. The azimuth circles of all gun carriages are graduated in degrees, and the numbers stamped upon these azimuth circles are such that when the vernier reads zero or 360° the gun will be pointed due south. Similarly, all position-finding instruments are set so that when the vernier reads zero the instrument will be pointed due south. Consequently, when any two telescopes or a gun, or a gun and a telescope, have the same azimuth reading, the telescopes or guns will, as far as azimuths are concerned, be parallel.

On any plotting board in constant use, the paper must be frequently changed, and the graduation of different circles on the paper requires very careful work. With the large number of different lengths of bases used, the lithographing of these circles is hardly practicable, and the custom grew up of placing the graduations and the numbers not on the circles but around the edges of the board where the radii prolonged would intersect the edges, in much the same way as in the rectangular protractor. In this manner the graduation for any one station or for any position of the gun can be put around the edge of the board once for all, and the paper or maps upon which the plotting is to be done can be changed as frequently as may be necessary. This means, however, that around the edges of the plotting board we will have at least three sets of graduations in close proximity one to another, and in times of excitement even the best trained plotter might easily make a mistake by using the wrong set of graduations.

To avoid the multiplicity of graduations there was devised a plotting apparatus based on the principle of the old form of parallel ruler which used the principle of the equality of the opposite sides of a parallelogram. In making use of this new principle, bars or rulers have been substituted for strings as being more convenient and because distances could be marked off on them.

The plotting from one of the stations, we will say station A, was done by a ruler pivoted at A. This ruler was placed in position by using a set of graduations around the edge of the plotting board based upon the point A as the center. In plotting from the point B two parallel connected rulers were used, one, the real marker, actually pivoted at B, and the other or auxiliary ruler pivoted at A. These two rulers were kept always parallel by being connected at about the middle of their length by a bar equal in length to the distance AB and pivoted to the rulers at the same distances from A and B, respectively. This connecting bar therefore remained always equal and parallel to the base line AB, and consequently the two rulers pivoted at A and B were always parallel to each other. If the auxiliary ruler which was pivoted at A was located in position by the reading on the graduations centered at A, then the ruler that was pivoted at B would evidently indicate the same azimuth on a circle centered at B. Consequently, both the A ruler and the B ruler could be set by using the same set of graduations, the A ruler by direct use of the graduations around the edge of the board, and the B ruler through the principle of parallelism and by use of the auxiliary ruler actually pivoted at A.

For reading azimuths and distances from the gun an additional or gun arm is used. This is pivoted at the point G, but for reasons which will appear later its azimuth is read, not by using the graduations around the edge of the board, but by using the graduations on a special small metal azimuth circle, the zero of which is adjustable. Consequently, under this system only one set of azimuth graduations is required around the edge of the plotting board.

The system of plotting so far developed therefore consists of a plotting room and two base end stations. At both stations, in the plotting room and on the platform close to the gun, are small electric bells, all of these bells being connected electrically with one master clock which causes all of them to give a single tap simultaneously and at intervals of 10, 15, 20, or 30 seconds, as may be desired. At each end of the base line there is an azimuth instrument oriented so as to read true azimuths. A man looking through the telescope keeps the vertical hair upon the previously designated portion of the target. As he follows the moving target with the telescope the vernier moves slowly over the scale and is watched by another member of the detachment. Every time the bell taps the last-mentioned observer reads the azimuth and communicates it at once by telegraph or telephone to the corresponding plotter at the plotting board. This plotter, immediately upon receiving this communication, sets his ruler and, as the bells have tapped in the two observing stations at the same instant, the settings made by the two plotters are of the same time, and the intersection of the rulers will indicate the position of the target at the actual instant the bells rang in the two observing stations. This point of intersection of the rulers is marked by a dot on the plotting board, and the gun arm can then be moved by the chief plotter to this intersection. The reading of the scale on the gun arm and of the azimuth on the gun azimuth circle, will give the distance and direction which the target had with reference to the gun at the instant the bell tapped. This information or certain deductions from it are then at once transmitted to the gun detachment for assistance in aiming the gun.

It is at this point, however, that the principal difficulty comes in. If the gun be pointed with the azimuth and range just determined, it will be aimed, not where the target is at the moment of aiming, but where the target was when the bells rang in the observing station some seconds before. Furthermore, even if at the time of firing the vessel was actually at the spot at which the gun was aimed it would have moved before the projectile could reach it. Consequently it is obvious that there are two very necessary corrections which must be made if the projectile is to hit the target; first, the correction for the travel of the target during the time between the observation of the target and the time of firing the gun, and second, for the travel of the target during the time of flight of the projectile.

If a dot be placed upon the board showing the position of the target at each tap of the bell, the direction of motion and the speed of the target will soon be shown by the row of dots and their distances apart. If it be assumed that the motion of the target will continue for some little time in the same direction and at the same speed, its position can be approximately determined for any particular moment in the future, and the gun can be aimed for the position the target will be in at that moment; or better still, since the distance of the target from the gun is known, the time of flight of the projectile can be figured out, the motion of the target during that time can be calculated and allowed for, and the gun can be aimed for a time corresponding to the arrival of the projectile at the target.

This allowance for the motion of the target can be made roughly by taking a scale and continuing the line of dots forward to the calculated time of arrival of the projectile. The gun arm could then be moved to this point and the reading of the direction and distance made directly. In actual practice, however, this is done in a much better way.

As I have stated before, the gun arm makes use, not of the azimuth graduations around the edge of the plotting board, but of the graduations on a special metal azimuth circle centered at the point G. The zero of the vernier of this azimuth circle is adjustable and the zero of distances along the gun arm is also adjustable. Instead, therefore, of pointing the gun arm to the predicted position of the target on the plotting board and reading off on a fixed scale and azimuth circle a predicted range and a predicted azimuth, the gun arm is kept pointed to the position of the target as last plotted and the readings to a predicted point are made by adjusting the zeros of the azimuth circle and of the range scale of the gun arm.

In working out the corrections for the motion of the target, it is convenient at the same time to make other corrections—a correction for the drift of the projectile depending upon the shape of the point, a correction for the effect of the wind, a correction for the difference in air resistance due to variations, barometric pressure, and a correction for a possible variation in the initial velocity of the projectile due to the temperature of the powder, etc.

These corrections are mechanically worked out by two members of the plotting detachment on two corrector boards especially designed for the purpose and furnished by the Ordnance Department, one giving the correction in azimuth and the other the correction in elevation. These boards are really mechanical integrators and the methods of using them are given in pamphlets that describe them and in the Coast Artillery manuals.

At the beginning of the plotting on any target, the zeros of the azimuth circle and of the range scale of the gun arm are set at their absolute positions. The first plotting gives the approximate range and the subsequent plottings give the motion of the target. As soon as the correctors get the approximate range they note it up on their corrector boards and later the travel. They then quickly and mechanically sum up the different corrections for these and the other items and then set off the correction by changing the zeros of the gun azimuth circle and of the distance scale on the gun arm.

At first sight it might appear that the application of these corrections makes the aiming of a gun very complicated, but it must be remembered that barometric pressure changes but slightly in an hour or so and that the average direction and velocity of the wind, not considering gusts, also remain fairly steady. The termperature of the air and the temperature of the magazine change slowly. The total correction to be applied is never very great and the changes in this correction from time to time are exceedingly small. Consequently, by the time the fourth or fifth plotting has been made the corrections will have been noted and the zeros moved. Thereafter the changes in the amount of the corrections will be very slight and only occasionally will any movement of the zeros be necessary. It thus becomes possible to transmit to the gun detachment an azimuth and range which if used in the aiming will cause the projectile and the target to arrive at the same point at the same instant.

Of course, all corrections in aiming based upon an allowance for the motion of the target, assume that the direction and speed of the target will remain practically unchanged from the time of observation to the time of arrival of the projectile. If the direction and speed of the target should be changed quickly and irregularly such corrections will do but little good, but it must be remembered that the targets at which heavy seacoast guns will be fired are usually very large vessels. On account of their mass the speed of these vessels can be changed but slowly, and when they turn they turn slowly and in circles of large radius.

THREE METHODS OF AIMING.

If the method of position-finding above described be used, it is not necessary that the aiming detachment see the target at all. To obtain success in this method of aiming, however, it is necessary that both base end stations be kept in good working condition, and that all communications be kept intact, so that all the data necessary may reach the plotting room and be sent thence to the gun. It is of course not impossible that during an action one of the position-finding stations may go out of commission or that one or more of the communication lines may be cut. In order that such an occurrence may not absolutely put the gun out of action it must be possible to fire without recourse to such an elaborate position-finding system.

There have, therefore, been adopted three methods of aiming:

Case 1.—Where the gun receives practically no information as to azimuths or ranges from a plotting room.

Case 2.—Where the range and elevation are given from the plotting room, but the azimuth is determined by direct sighting with certain corrections for the motion of target, etc.

Case 3.—Where both the range and azimuth are sent from the plotting room as has been described above.

For use in cases 1 and 2 a modern seacoast disappearing-gun carriage has an elevated platform where the gunner stands and observes the target through a sighting telescope. At this sighting telescope he is, of course, exposed to view and to fire.

In firing by case 1 the gunner points his telescope directly at the target, guessing at the range from the first shots and making such subsequent corrections in range and azimuth as may appear to be necessary from observation of the fall of the projectiles.

In firing by case 2 the gunner on the sighting platform uses the telescope, but he obtains his range and some data as to corrections in azimuth from the plotting room. In using this case the same general data as in case 3 are sent to the plotting room. The plotting is done as in case 3 and, as in case 3, information as to range and elevation is sent to the loading detachment, but instead of sending data as to the azimuth at which the gun should be aimed, there is merely sent to the gunner at the sighting platform, information as to the total of the corrections in azimuth. This he makes use of by setting the axis of his telescope a little to the right or left so that it does not point in the same horizontal direction as the gun, but in such a direction that if the cross hair of the telescope be kept on the target when the gun is fired, the projectile will go not to the spot at which the telescope is pointed, but to the spot at which the target will be when the projectile has gone that distance.

In actual service, case 2 is the one most used by our seacoast artillery since it has the great advantage that the firing of a gun at any particular instant is not necessary as in case 3.

Of all the corrections in azimuth which are applied, the largest is usually that due to the motion of the target and this correction changes slowly. Therefore, if case 2 be used and the proper correction for all elements be once sent to the gun and applied to the sighting telescope, subsequent corrections will be infrequent and slight, and if the gunner keeps the vertical hair constantly on the target the gun will be constantly kept trained in azimuth and can be fired, as far as azimuth is concerned, at any instant.

Likewise, the member of the detachment at the elevating wheel keeps the gun set at the elevation sent him from the plotting room. Since this elevation will evidently change at a fairly uniform rate, a skilled man soon learns to change the elevation continuously, and at such a rate that it will always agree accurately with the elevations received from the plotting room just as they are received. The gun will, therefore, be always trained in elevation and can be fired whenever it is loaded and just as rapidly as it can be loaded.

In firing by case 3, on the other hand, it is essential that the gun be fired at exactly the movement for which the aiming data were calculated.

Mortar Fire.

Mortars are usually mounted in deep pits from which the target can not be seen. Consequently, case 3 is the only one applicable to mortar firing.

The initial velocity of mortars is much less than that of direct-fire guns and the projectiles are fired at high angles, and, consequently, the time of flight is much greater than that of direct-fire projectiles—in some cases as much as one minute and a half or two minutes. Furthermore, it is not possible in mortars as in direct-fire guns to keep the mortars constantly trained in azimuth and elevation. They can be loaded only when their axes are horizontal and must be trained, in elevation at least, after they have been loaded. Furthermore, the blast effect of the discharge of mortars is so great that time must be given to the men to withdraw several yards to the rear. Consequently, some time must elapse from the time when the mortar is set to the time when it is fired. During this time and that required for the plotting and transmission of data, it is possible that either the direction or speed of the target may have changed, and in order not to waste ammunition in case this should have occurred an additional precaution is used in mortar firing.

In addition to the base-end observing stations, there is an additional station provided at which the battery commander or some especially designated man is stationed. At the same time that the data for loading are sent to the detachment in the pit, information is sent to this special station as to the azimuth which the target should have from that station at the particular moment that the mortar should be fired. The azimuth instrument in this station is set at this azimuth and the observer looks through it. If, when the instant for firing comes, the target is passing over the vertical wire, the mortars are fired. If the target is very nearly there they are fired at the instant the target crosses the vertical hair, because the difference between the azimuth at which the instrument is set and that used in setting the mortars has been calculated for the time for flight. If, however, when the calculated moment for firing arrives the target is far off from its predicted position, the observer knows that something is wrong and withholds fire until after a new prediction has been received and the mortars have been relaid. The use of this additional instrument, therefore, acts as a check upon the plotting and aiming system.

SHORT HORIZONTAL BASE SYSTEM.

The system of horizontal position-finding just described is based upon the use of a very long base line and telescopes at both ends of this base line. Accuracy in the use of this system is possible only when the exact length of the base line is known, when the zeros of azimuth of the two instruments are exactly parallel, and when the instruments are read at exactly the same moment. Furthermore, it may happen that while a target can be seen very clearly from one station, smoke or some other obstacle may interfere with its view from the other station.

In order to overcome these and other difficulties an attempt has been made to utilize short self-contained horizontal base instruments.

The essential principle of these instruments is as follows: Two similar object glasses are mounted a known horizontal distance apart and with their optical axes horizontal and parallel. Immediately behind each object glass a prism or mirror is placed in such a position as to change the direction of the rays of light 90° in a horizontal plane so that after passing through the prisms the rays will travel approximately toward the other object glass. Midway between these object glasses a pair of prisms is placed, one for the rays coming from each object glass, these prisms being so arranged as to again turn the rays of light 90° in a horizontal plane and so that these rays become parallel to the directions which they had after they passed through the object glasses. These central prisms are, in addition, so connected up with the eyepiece as to fuse the rays of light together, with the result that the observer, looking into the eyepiece sees two images in the same field and nearly superposed. Incidentally, also, these prisms are so arranged as to cause the image as seen by the eyepiece to be erect.

Under normal conditions the two images seen through the eyepiece will be exactly superposed only if they are images of an object at an infinite distance away. The images of objects at finite distances can be made to superpose exactly by the rotation of one or both mirrors or main prisms, or by the rotation of an auxiliary prism interposed in the path of the rays of light coming from one of the object glasses. To make the two images of any object at a finite distance exactly coincide, a rotation of this auxiliary prism is necessary and the amount of the rotation required is dependent upon the distance of the object. If we know the amount of movement necessary to make the images of an object coincide, we can figure out the distance of the object or, what is better, the scale showing the amount of this rotation can be so marked as to indicate, not the amount of rotation itself, but the distance of the object, in yards or as such other units as may be desired.

What the instrument really does is to measure the angle subtended at the target by the distance between the two object glasses and to convert this angle into distance. The angle is always very small and becomes smaller the greater the distance of the object. The accuracy of the reading of the instrument depends, therefore, upon the accuracy of the reading of a very small angle. Furthermore, the use of the instrument depends upon the exact superposition of the two images of an object. In order that the superposition may be exact the outlines of the objects must be very clear and distinct, and the farther away the target is the greater the difficulty in obtaining in a telescope clear and distinct views of it.

The instrument, therefore, has limitations and though many types have been tried none have been found satisfactory for reading long ranges.

The longer the instrument, of course, the greater the base line used in the triangulation, but as the length increases there seems to be an increase in the difficulty of keeping the instrument rigid under temperature changes.

At the present time there has been adopted in the service a short horizontal-base instrument which seems to be quite satisfactory in reading ranges for rapid-fire guns up to about 6,000 yards under good atmospheric conditions. Larger instruments have also been introduced and are effective at slightly increased ranges. It is possible that the future may show that it is possible to develop still better instruments, but it is the opinion of the writer that owing to the optical principle upon which these instruments work and the difficulty of obtaining very distinct images of distance objects, it will never be possible to develop self-contained horizontal-base instruments that will be even fairly effective in any except most unusual atmospheric conditions at ranges greater than 10,000 yards.

This instrument reads the distance of the object from the instrument, and it can be made so as to read azimuths, in addition. It is ordinarily used with rapid-fire guns and is mounted not far from the guns, so that the distance shown by the instrument will be approximately the range of the target from the gun. No plotting, therefore, is necessary and slight errors of range are of but little importance. To be of use with guns not near the instrument, plotting or relocation is necessary.

VERTICAL BASE POSITION-FINDING SYSTEM.

The principle upon which the use of the vertical base position-finding system is founded is triangulation in a vertical plane, making use of a right triangle whose sides are as follows: First, a vertical line downward from the position of the instrument to the projection of this point upon the plane of sea level; second, the horizontal line from the foot of the vertical line to the target; third, the line from the target to the telescope. Since the triangle is a right triangle it is necessary to measure but one of the acute angles. The direct measurement of the angle at the target is, of course, impracticable, but the other acute angle, that at the telescope, is available and can be measured.

It should be noted, however, that in the cases which happen in practice the vertical side of the right triangle is always much smaller than the horizontal side, the elevation of the instrument practically never exceeding a few hundred feet and the distance of the target being seldom less than a thousand yards. Consequently, of the two acute angles of the triangle the one at the target is usually quite small and the one at the telescope is not much less than a right angle.

In practice, therefore, it has been found simpler to measure, not the angle between the vertical line and the line from the telescope to the target, but the complement of this angle, that is, the angle of depression of the line to the target below the horizontal plane passing through the telescope. This angle of depression is equal to the angle of the triangle at the target and is always fairly small.

The sites chosen for the stations to be used in this system are usually the highest that are available or that can be made available, consistent of course with other requirements, such as a fair degree of concealment, convenience of location with respect to the gun, a clear view of the probable field of fire, etc.

The instruments used are of special design and of very careful manufacture. The telescopes are large and powerful. The observer looks through the telescope at the target and moves the telescope until the horizontal hair appears to coincide with the water line of the target.

All that is then necessary is to measure the angle of depression, and to make the calculation for the distance which is mathematically equal to the length of the vertical base of the triangle divided by the tangent of the angle of depression (which angle is equal to the angle of the triangle at the target). Since, with a given length of vertical base, the distance of the target is a function of the angle of the depression, it is simpler and easier in practice to have the calculations worked out beforehand and to have the scale on the instrument so graduated as to read, not angles, but the calculated distances to the target.

In spite, however, of all possible care in the design of the instrument and skill in its manufacture, this system of position finding possesses certain inherent difficulties which place a limit upon the degree of accuracy obtainable. Some of these difficulties are dependent upon the difficulty of the determination of the actual length of the vertical base, and the remainder upon the difficulties in obtaining a proper value for the angle of depression.

The upper end of the vertical base is, of course, the center of the instrument. This point is fixed and its elevation can be measured, with any desirable degree of accuracy, with reference to a selected bench mark, to mean sea level, to mean high water, to mean low water, to the zero of any fixed tide gauge, or to any other fixed point; but the quantity which should properly enter into the calculation of the distance of the target is not the elevation of the instrument above any one of the planes mentioned, but the difference in elevation between the instrument and the actual point of the target apparently intersected by the horizontal hair of the telescope.

The targets used with this system are, of course, intended to be the enemy's vessels, and the attempt is made to waterline these vessels as seen in the telescope. This is where the difficulties come in. In the first place, the level of the water surface in all our harbors, and hence the length of our vertical base line, varies with the tide. The difficulty due to tidal rise and fall is, however, one that is easy to eliminate since the height of the tide at any moment can be predicted closely by tidal tables, or what is better, can actually be observed on a tide gauge. Information as to the height of the tide at any moment can be quickly transmitted to the observer at the instrument who can make the proper adjustment of his instrument. The tidal error is, therefore, one for which proper correction can be made from time to time.

To waterline the target, however, that is, to fix the cross hair of the telescope on the portion of the target that the water is just touching is not an easy thing to do. Warships are painted a dark green not greatly different from the apparent color of the water when seen at a distance and due to the reflection of the ship in the water the exact determination of the water line is difficult even when the ship is not in motion. When the ship is in motion and when there are waves the difficulty is much increased.

In all our harbors there is always more or less wave action. Some of the waves are small, splash up against portions of the target, and are depressed in others. But these smaller waves, although somewhat confusing to an untrained observer, do not give as much trouble as the longer swells which raise and lower the target without showing visibly upon it. These long swells are always present to a greater or less extent; they are of irregular periodicity, and are almost certain to influence the readings of the instrument.

When a vessel is in motion the water is always banked up at and near the bow. A little distance further astern the level of the water against the side is much depressed, thence to the stern of the vessel the water level is alternately raised and lowered.

The extent to which the water is banked up in some places and depressed in others depends upon the speed of the vessel and is greater the faster the vessel is going. To look through a telescope at a moving vessel and attempt to water line it is extremely difficult. Even the best trained observers are very prone to make mistakes, usually in the way of assuming that the water line is higher than it really is.

It might appear at first sight that the errors which would be made in water lining a vessel, due to the causes mentioned, would be comparatively small, only a few feet at most. This may be true, but it should be noted that the effect of errors of this character is really to change the length of the vertical base line which is used in calculation. If, for instance, the vertical base line is approximately 50 feet and an error of 5 feet should be made in water lining the vessel, this error is one-tenth of the length of the base, and the calculated distance would, therefore, be in error by approximately one-tenth of that distance.

The difficulties of waterlining increase rapidly with the distance of the target both because of decreasing visibility and the difficulty of seeing the troughs of the waves against the vessel and, therefore, of placing the horizontal cross hair so as to about balance the crests and troughs.

In the measurement or observation of the angle of depression there are other sources of error, a minor one due to the curvature of the earth's surface, and a more serious one due to refraction.

The curvature of the earth's surface is an element which must be taken into consideration. The departure of the surface of the earth from a horizontal plane increases approximately as the square of the distance. The error thus introduced is an easily calculable quantity; it can, therefore, be allowed for with a fair degree of accuracy.

Refraction in the vertical plane is always present in the passage of light rays through the atmosphere and is due to the decreasing density of the air as one ascends.

For observation on stars near the zenith, refraction is almost negligible except for use in very careful astronomical observations, but for observations on stars at or near the horizon refraction becomes very great, the general effect being to elevate the apparent horizon by more than one-half a degree of arc. If the elevation of our instrument is about 100 feet, and it is frequently much less than that, and the distance of the target is 10,000 yards, and it is frequently much more than that, our vertical base line is only about one three-hundredth of the horizontal distance to the target. Consequently the angle of depression with which we are dealing is only about one-fifth of a degree or approximately one-third of the amount of refraction. Consequently, it is evident that refraction in depression position finding is an extremely important element.

Were refraction constant, however large it might be it could be allowed for, but unfortunately it is not a constant quantity.

The line of sight from the instrument to the water line of a distant target passes for a considerable distance through air that is almost in contact with the water and the temperature of which is to a considerable extent affected by the temperature of the water as well as by the temperature of the air above. The larger part of our seacoast forts are situated at the entrances to navigable harbors. The depth of water in the harbors is usually not very great and the sun is apt to warm up these comparatively shallow harbors to several degrees above the temperature of the ocean outside. With the ebbing of the tide the warm water passes to the sea, usually in well defined currents, so that the water in our harbors and over which our depression position finding telescopes have to look are apt to contain irregular streaks of warmer and cooler water with considerable resulting irregularity in refraction.

When depression position finding instruments were first introduced it was the idea of their inventors that the amount of refraction could be easily calculated when the reading of the local barometer and thermometer were known and could then be allowed for. It was soon found out, however, that this was not true and that even an approximate determination of the effect of refraction could be arrived at only by actual observation at the time; that is, by sighting the telescope at some object in the water whose position was known.

The objects whose position and distance from the instruments are known are called "datum points" and consist usually of piles or clusters of piles or of some similar structures.

At first it was thought that a single datum point would be all that was necessary, but it was soon discovered that a telescope adjusted on a datum point at a comparatively short distance would not necessarily read the correct distances when sighted at a datum point much farther away. Consequently, a multiplicity of datum points was found to be necessary, and the attempt was made to place datum points, some at about 3,000 yards from the observation stations, others at about 6,000 yards, and still others at about 9,000 yards.

The observing instruments used are adjustable for two corrections; one, a tidal correction intended to allow for the varying length of the vertical base; and the second, a refraction correction intended to allow for atmospheric refraction. In practice, both corrections have to be used together to allow for refraction. The instrument is first adjusted for the tidal correction, according to the reading of the tide gauge. It is then sighted at a distant datum point and adjusted by the refraction correction adjustment so as to read the correct distance of that datum point. It is next turned to a nearer datum point and, if it does not read correctly and adjustment is made as if for tidal difference so that the instrument will read the correct distance to this nearer datum point. With care and the alternate use of the two datum points, it is usually possible to adjust the instrument so that will read fairly correctly the distances to both the near and the far datum points and will presumably, therefore, give approximately accurate readings for distances between the two and for distances slightly beyond the farther datum point.

The methods of making these adjustments are given at length in the manuals on the subject and need not be gone into further here.

In spite of the fact that more care and thought seems to have been expended upon the development of the depression position finding instrument than on any other observation instrument, the best that can be said of it is that except under unusually favorable circumstances it gives approximate distances only.

Of course, the longer the vertical base—that is, the higher the instrument—the less the probable error of its reading. Where very high sites are available the instrument is therefore quite serviceable, but unfortunately the country is so flat along the greater part of the coasts that high sites are not available and we can raise our position-finding instruments to high elevations only at the expense of making the stations quite conspicuous.

The first experiments with the depression position finding instruments were made at Fort Wadsworth, New York Harbor, where fairly high sites were available, where the water was comparatively quiet, and where the ranges at which observations were made were not very great.

The results of these experiments were so satisfactory and the simplicity of the vertical-base system which read distances directly without plotting was so great, compared with the long horizontal-base system, which requires the simultaneous readings from two ends of a base line and the subsequent plotting of position, that it was adopted as the standard position-finding system for seacoast use.

It was then believed that a vertical base 60 feet long would give sufficiently accurate readings at the ranges desired and the Board of Engineers at once designed instrumental towers to be used along our low sandy beaches. This tower consisted of a steel framework supporting a house at the top. The pillar or pier for supporting the instrument was built independently of the tower proper and consisted of a concrete column going all the way to and into the ground. To keep this column from vibrations due to the wind, it was surrounded by a metal cylinder attached to the tower framework, but nowhere touching the concrete of the column, nor was the floor of the observing room allowed to touch the column.

The first of these towers built was a one-story tower, the plotting being done on one side of the same room containing the instrument. Before any additional towers were constructed, however, the plans were changed slightly so as to make the upper part of the tower consist of two stories, an upper room for observation and a lower one for plotting. The plans for these towers are shown in mimeograph No. 42 and its supplements.

It so happened that just at the time that this type of tower was adopted as a standard, a large appropriation for fire control was available and many towers were ordered to be built, distributed practically along our whole coast. At small forts only one or two of these towers were built, but at some of the larger ones as many as eight were constructed.

Unfortunately, the harbor entrances at all of our South Atlantic and Gulf ports, and occasionally elsewhere, are bounded by low sandy shores. No sooner did these towers begin to spring into actual existence on the low sandy beaches than it became clear that they were entirely too conspicuous. Occasionally it happened, near the north end of the Fort Monroe reservation, that towers could be built in the midst of woods or had a wooded background which made it possible to conceal them, but in most places no such background existed and it was evidently impossible to conceal the towers. Being, as it were, the head and brains of the whole fire-control system, it was expected that they would naturally be the targets used by the enemy. It was, therefore, thought that they were too vulnerable and the type was abandoned. In fact, before many of them were actually completed they had been declared to be obsolete.

Experiments were then made with lower stations, some having an instrumental height of 40 feet, some of 30 feet, and some of 15 feet only. These were found not to be satisfactory and finally the idea of depending exclusively upon this depression position-finding system had to be given up except for localities where high sites were available, and even then for comparatively short ranges only.

THE THREE SYSTEMS OF RANGE FINDING.

We have, then, three essentially different systems for determining ranges: First, the long horizontal-base system; second, the self-contained short horizontal-base system; and third, the vertical-base system.

The first, the long horizontal-base system, is the most accurate, but there are a number of adherent disadvantages in such a system. First, in order that the position finding may be sufficiently accurate the base must be very long and must be suitably oriented with regard to the direction of the target. Locations for suitable base end stations are not always available. Then again, if there are a number of vessels coming in at the same time, and if the vessels happen to be of the same class, as is quite probable, in future attacks, it is quite difficult to insure that the instruments at the two ends of the base line will be sighted at the same ship. This difficulty increases with the length of the base line. A ship that appears the farthest to the right from one station may not necessarily so appear to the other, or the one that appears foremost or rearmost from one station may not have the same relative position from the other. Unless, therefore, the ship it is desired to use as a target has very special characteristics that distinguish it from the other ships, mistakes in the identity of the target may easily be made.

In fact, during the maneuvers of 1905 at Fort Monroe, a mistake of this kind actually did occur. In making the run by, the larger ships were preceded by destroyers making a smoke cloud. Through this smoke the battleships could be seen but dimly. The target used by one end of a base line was not the same as that used by the other. When plotted from these erroneous observations it so happened that the first point plotted looked as if it might be the actual location of a ship, but as the plotting was continued the mistake became evident as the plotted path, instead of following the channel, passed right through the position of a big stone fort.

The depression instrument is much less accurate than the horizontal base system, but with this instrument only one view of the target is necessary and no errors due to failure of identification can occur. However, in order to make this instrument available at all, the target must be seen with sufficient clearness to make it easy to water line.

The short self-contained horizontal base system is much less accurate than the long horizontal base system, but is probably more accurate than the vertical base system when used from low sites, and less accurate than the vertical base system used from high sites.

Identification.

After the errors in the use of the vertical base system due to refraction were found to be irremediable, and the possibilities of errors due to mistakes in identification in the use of the long horizontal base system had been shown, it was suggested that the two systems might be used together so as to avoid both errors. That is, it was proposed that the instruments at both ends of the horizontal base should be depression instruments fitted with azimuth circles. When the target had been designated, not only would the azimuths to the target be read but the approximate range as shown by the depression principle also. The position of the target given by the azimuth readings from the two ends of the base line would then be marked on the plotting board and if this position accorded fairly well with the distances from the two stations as shown by the reading of the depression angle, it was considered that it might be safely assumed that both instruments were pointing at the same target. If not, it would be evident that a mistake had been made in the identification of the target and the cause of this trouble would be at once investigated and corrected.

POSITION FINDING FOR BATTERIES.

In the preceding discussion the subject of position finding has been discussed as if each gun had its own independent base line and plotting room. Although nowadays this is to a great extent true of the larger guns that are being installed, it is not true now of the smaller guns, and has only recently been true of the larger ones. Structurally, emplacements have usually been united into batteries of two, three, or four, and, in general, it has been expected that all the guns of a battery would use the same target at the same time. Theoretically, if two guns of a battery are aimed with the same azimuth and elevation, the two points of fall of the two shots should be at the same distance apart as the two guns and the line joining them should be parallel to the line connecting the gun centers. This might at times throw the gun off the target and a correction is sometimes necessary. In practice, therefore, it has been customary to determine the range and azimuth of the target from one point of the battery known at the directing point, usually one of the gun centers, a point midway between the gun centers in a two-gun battery or the location of the middle gun in a three-gun battery. The azimuth and elevation with which a gun not at the directing point of a battery should be fired are, of course, very slightly different from what they would be if the guns were at the position of the directing point, but the difference is not great either in azimuth or elevation, seldom amounting to as much as a half of a degree in azimuth and more than a very small fraction of a degree in elevation.

The actual differences can easily be calculated, or better still they may be shown graphically on what is called a "difference chart." When the azimuth and elevation corresponding to the directing point are received at the gun, the corresponding differences can be quickly read off this chart and can then be applied in aiming the gun.

Battery Commanders' Stations.

It would appear at first sight that the logical station of a battery commander is at his battery, and at such a position at his battery as to enable him to best oversee the work of the detachment. As has been stated, the earlier emplacements constructed contained in each battery a plotting or relocating room, and consequently when the battery commander was at the battery he could at the same time oversee the plotting or relocating.

When the plotting room was moved to an observation station either in connection with the depression position finding system or with the horizontal position finding system, it was evident that the battery commander could not personally oversee both the operations in the battery and the operations in the plotting room. Either he must stay at the battery and leave the supervision of the plotting to one of his subordinate officers, or he might go to the primary station and leave the supervision of operations at the battery to one of his assistants. In general, of course, it would appear that his proper place was at the battery.

With the adoption, about 1904, of what was called the Barrancas system other conditions were introduced. As will later be explained more in detail, the essential principle of this system was the installation of equal and parallel base lines, and this was obtained by having a set of primary stations collected together in one group, and a set of secondary stations in a similar group. In general, there was a group of primary stations for each fire command, the fire commander occupying the central primary station and the other primaries being assigned to the different batteries. This system was invented by an officer who at the time was of the rank of major and a fire commander, and in order to insure that the system would work well he wanted to have his battery commanders near him. He therefore required that each battery commander should take station at his primary station, leaving affairs at his battery to the charge of his lieutenants.

It was intended that the fire commander should select the vesse to be used as the target for each battery and should then telephone each battery commander as to the target he should use, but in order to be sure that a battery commander was using the proper target, the fire commander might walk into the battery primary, which was only a few feet away, and see that the instrument was actually observing the proper target. Or without even telephoning, the fire commander might, if he desired, walk into a primary station and himself point the telescope on the proper target. This system, of course, contributed largely to the unity of action of the different batteries of a fire command and was quite satisfactory to the fire commanders. The captains, however, were in this manner located at considerable distances away from and frequently out of sight of their batteries and in positions where their responsibilities were in fact comparatively small. It was natural, therefore, that the captains should clamor for a system which would send them back to their batteries.

When the towers for use with the depression position finding system had been built at Fort Monroe there were several cases where the towers were located slightly to the flank of and to the rear of the batteries to which they pertained, especially was this true in the case of the most powerful battery then in commission at that fort, a three-gun 12-inch battery.

It was soon discovered by the commanding officer of this battery that from the observing room of the tower he could obtain an excellent view of operations on at least two of his loading platforms, and that by means of a megaphone he could communicate his instructions to the detachments in those emplacements. Consequently, when it was decided that the captains should go back to the batteries there was a demand that stations be built for them from which they could not only see what was going on at the batteries but could also observe the effects of their fire.

The typical plans of the older batteries all showed small crow nests on the flanks of the batteries, but in general these crow nests were too small for occupancy by more than a single observer, and moreover, they were very inconveniently placed for an officer whose duties required that in addition to observing he should supervise the work of the battery. (See Plates XIV to XX.)

At the same time when the subject of providing battery commanders' stations at the batteries was being considered, the writer of these notes was the constructing officer at Fort Monroe, Va. The most modern 12-inch battery, Battery Parrott, was about to go into commission and there happened to be in rear of it a part of the old system of fortifications, a water battery then being demolished. The suggestion was therefore made to the battery commander assigned to this battery that an experimental station for him might be built on the top of the old water battery. Trial showed that the old battery was a little too far to the rear of the new one, and the experimental station was therefore located immediately in rear of the center of the new battery.

This experimental battery commander station was built of scrap lumber saved from the concrete framework. In connection with it there was provided a plank battery commander walk on the same level as the floor of the station and extending from one side to the other of the central traverse of this battery, immediately behind the traverse and just in front of the station. At the end of this walk stairways led down to the loading platforms, and thus permitted the battery commander to proceed quickly from the station to either of the loading platforms. The height of the battery commander station was such that a person in the station or on the walk could just see over the top of the battery, which was of the horizontal crest type. The station was roofed over and was provided with the character of observation windows then standard in fire-control stations. Beneath the station and about on the loading platform level there was built a plotting room, and by means of an opening in the floor of the station the battery commander could look into the plotting room and see, if he desired, exactly how the plotting was being done. As soon as completed this experimental station was put in use, and as experience showed them to be desirable modifications were made, these modifications being easily possible because the structure was of timber.

Finally, after about a year's experience, a satisfactory type of battery commander station was developed and the original experimental station was replaced by concrete. Similar structures were soon built for many other batteries throughout the country (see the thirty-third supplement of mimeograph No. 42). The type of station thus evolved consists essentially of a small two-story concrete structure. The upper story is for observation by the battery commander and his assistants and contains some telescopes and such other observation instruments as may be necessary. It is placed on such a level that the battery commander can look over the top of the battery and can have a clear view of the field of fire of the battery. The lower story, which is on about the loading platform level, contains the plotting room. Communication—that is, speaking—between the two levels is provided for by means of a large voice tube connecting the battery commander's room with the plotting room and there is a conveniently located stairway which permits a person to go quickly from one room to the other. In order that the battery commander may be able to move rapidly from his station to either of the loading platforms or, if he desires, to go merely to a position from which he can see into the platform, there passes in either direction from the battery commander station an elevated walk known as the battery commander walk. The floor of this walk is at the same level as the floor of the battery commander station so that a person standing on it can see over the top of the battery. It is located immediately behind and is attached to the rear wall of the central traverse and at each end has steps going down into the loading platform.

The battery commander stations built in accordance with the plans just described proved so satisfactory that it was decided to embody a station possessing all the most desirable features in the mimeographed plans of the next disappearing emplacements to be published. This was therefore done in mimeograph No. 109 (Plate XXII), which gives the plans of the emplacements for 14-inch guns.

The stations added to the older batteries were necessarily built in rear of the batteries because it was evidently impossible to incorporate them in the main structure of the emplacements. It is evident, however, that the stations, and what is more important still, the plotting rooms, would be better protected from flank fire if they had actually been built into the central traverse. This, of course, it was possible to do in batteries to be thereafter constructed and the station and plotting room are shown in mimeograph No. 109 (Plate XXII) as built into and forming part of the central traverse.

In the battery commander stations built in the rear of the top of the traverse the floor is a few feet below the level of the top of the emplacement, but at such an elevation as to enable an observer to easily look over the traverse. The stations are shown as covered by a splinter-proof concrete roof and observation windows are shown around three sides of the station of a design which had already been shown to be satisfactory.

The battery commander's walk in this design is quite similar to those built for the older batteries, passing along the rear of the central traverse and behind the battery commander station which is entered from the walk. At each end of the battery commander's walk, as in the old design, there is a staircase leading downward to the upper platforms of the main staircases, which extend downward from the loading platform to the ground level. They therefore serve to provide easy communication, not only from the battery commander's walk to the loading platform, but also from the battery commander's walk to the ground.

In the design shown in mimeograph No. 109 (Plate XXII) the plotting room is placed not directly beneath the battery commander station, but is pushed farther forward into the body of the traverse, leaving behind the plotting room a corridor which serves as a communication not only to the plotting room but also between the two loading platforms.

In order that the battery commander in his station may be able to talk conveniently to persons in the plotting room, there are provided wide slots extending from the ceiling of the plotting room rearward and upward to the front wall of the battery commander station. These slots are so shaped that, in addition to talking through them, the battery commander can actually observe what is being done on the plotting board. (See detail on sheet 2, mimeograph 109.)

Mimeograph 109 remained the standard upon which large gun emplacements were designed until it became necessary to design the Panama batteries. These batteries, as has been stated, were of the new one-story horizontal ammunition service type, the magazines having their floors on the same level as the loading platform and having their concrete ceilings surmounted by earthen covers.

A battery commander's station has been provided for each emplacement and is located on top of the rear of the magazine traverse, and on the side of that traverse toward the loading platform. The side slopes of the traverse have been so designed as to permit a partial view of the loading platform to be obtained from the battery commander station. (See Plates XXIII, XXIV, and XXV.) The floor of the station is sunk into the top of the traverse and is placed at such a height that a view can just be obtained over the traverse. The front and side walls are, of course, of concrete but are raised only from 4 to 6 inches above the level of the surrounding earth and are finished off on top in slopes running down to the earth.

The station is entered from the rear and can be reached by a walk which leads sideways to the side slope of the loading platform or by a staircase which leads downward to the magazine level.

The plotting room is placed on the loading platform level which, in this case, is the same as the magazine level and is almost vertically under the battery commander station, the usual voice tube communication between the two being provided.

In the Panama batteries the battery commanders' stations are usually 15 feet square and their floors are entirely on one level. Among the functions to be performed from the battery commanders' stations is that of telephone or speaking-tube communication. This is usually attended to by members of the detachment provided with head sets. It is, of course, not essential that these telephone men should be so situated as to get a view of the field of fire, and if they can get such a view it is not improbable that their attention might be thus distracted from their proper work. Furthermore, it is thought that they are perhaps unnecessarily exposed to fire.

A modification has therefore been made in the standard design of battery commanders' stations, the floor of the stations being broken into two levels, the forward level at a height convenient for observation and the rear some 3 or 4 feet lower. The telephone speaking tube terminals are placed on this lower level and stools are to be provided for the telephone men, who are thus put in a position where they are much safer and where their attention is not likely to be distracted from their proper duties by the sight of what is going on in the field of fire. This new type of station, with two floor levels (see Plate XXI and XXVI), may now be considered as standard. The battery commander's walk is now placed on the lower level, and therefore no longer affords a view of the field of fire.

In all recent designs, both those for the Panama and for other batteries, short stairways have been provided leading from the battery commanders' stations up to the top of the traverse, so that ready access is available should it be necessary for the battery commander or some one else to get hastily on top of the traverse. The question of the proper kind of roof for a battery commander's station is still under discussion.

The first experimental battery commander's station built at Battery Parrott was provided with a light frame roof for the protection from the weather of the personnel and instruments. Incidentally, the presence of a roof made it possible to lock the station up securely when it was not occupied.

When the standard designs of battery commanders' stations were prepared it was proposed to build the stations of concrete and they were provided with splinter-proof concrete roofs. The same design with some improvements in detail was embodied in Mimeograph No. 109. (Plate XXII.)

To observe over the battery requires that the eyes of the observer should be a foot or so above the upper surface. A little space must be provided above the head of the observer, and if above this a fairly thick concrete roof is to be built, the top of the roof necessarily projects a considerable distance above the top of other portions of the traverse. It is therefore more or less conspicuous and can be seen by the enemy. Not only may it draw the enemy's fire, but it may in addition be used by him as a point from which to locate the guns. Incidentally, in time of action it might be struck and cause the detonation of a projectile which, if it were not for the roof, would have passed harmlessly by.

It was therefore thought that for many reasons it might be better that the station, at least in time of action, should have no roof at all. Consequently, in most of the larger Panama and later batteries the battery commanders' stations have been provided merely with removable iron-pipe framework, upon which awnings could be spread to protect the detachments during drills and target practice from the sun or weather.

Battery Commanders' Stations for 6-Inch and Smaller Batteries.

As was the case with the early designs for large gun emplacements, the earlier designs of emplacements for small and medium caliber guns usually included small observation stations or crow's nests. (See early design for 3-inch emplacement, Plate III, for 5-inch emplacements, Plates VI and VII, and for 6-inch emplacements, Plate IX.) The crow's nests shown on these earlier drawings were usually quite small; sometimes they were shown as circular, sometimes as square, and their diameter usually did not exceed 5 feet. They were therefore intended for observation only and were hardly suited for use as battery commanders' stations. The 1902–03 designs for 6-inch emplacements (Plate X and XI) showed these stations slightly larger, about 7 feet square, and that remained the standard for 6-inch batteries until the Panama 6-inch emplacements were designed. These were provided with battery commanders' stations similar in size, shape, and location to those provided for the large Panama batteries and heretofore described. (See Plate XII.)

The 1903 designs for 3-inch emplacements (Plate V) showed no crow's nests or observation stations, probably because at that time it was customary to consider small rapid-fire batteries as intended primarily for the protection of submarine mines. They were, therefore, assigned to the mine commands, formed part of those commands, and were supposed to have little use for battery commanders' stations. However, some years later, instructions were issued to build battery commanders' stations at these small batteries also. These battery commanders' stations were placed at the center of the rear of the top of the traverse and were reached by walks passing along the rear of the top of the traverse and thence along the sides to the loading platforms of the guns. Some of the earth covering of the top of the traverse was removed to provide space for the station and the walk ways leading to it. The station was surrounded by thin concrete walls. Usually it was provided with a corrugated iron roof.

Battery Commanders' Stations at Mortar Batteries.

In the drawings of the 1898 type of mortar battery (Plate XXVIII), small crow's nests are shown on top of the flank traverses, and where mortar batteries of this type were built in such positions that the fields of fire could be seen from them, such crow's nests were usually provided. These crow's nests, however, were small and usually not well fitted for the use of a battery commander.

In 1905 there was in session at Fort Monroe a board of Artillery officers revising the Drill Regulations for Seacoast Artillery. The writer was at that time constructing officer there and had recently completed the experimental battery commander's station at a large direct-fire battery, described a few pages above. He therefore offered to undertake the development of a battery commander's station for mortar batteries.

The mortar battery at Fort Monroe is of the type shown in figure 4, Plate XXVII, and consists of four mortar pits in a line with four mortars in each pit. The pits are open to the rear and are separated from each other by traverses extending backward from the front parapet. To the rear these traverses end off in gently rounded slopes. Shortly before the time mentioned this battery had for tactical purposes been divided into two smaller tactical batteries of eight mortars each, and each tactical battery had, therefore, a traverse extending backward between its two pits.

The top of the rear slope of the central traverse of one of these smaller tactical batteries was selected as the site for the experimental battery commander's station. The station was built high up on the rear slope of this central traverse and was placed at such an elevation that it was just possible to see over the top of the battery. At first the station, which was about 5 feet wide by 7 feet deep, consisted merely of concrete walls on three sides, the rear being open. The concrete walls were about a foot thick and 5 feet high measured above the concrete floor, while in front they projected about a foot above the upper surface of the earth of the parapet. In the center of the station was a pier for the battery commander's telescope. No roof was provided at first, but some months later, at the request of the local battery commander, a light frame and supposedly removable roof was added, with the understanding that the roof was a mere temporary convenience for protection during drills. However, before long the garrison had found it convenient to suspend electric wires from the framework of the roof so that it could not have been removed without disarranging a large part of the wiring.

Just behind the battery-commander station and on a level a few feet below the floor of the station a plank walk was built extending out to both flanks far enough to permit a person standing near the end of the walk to easily see down into the mortar pit.

A few months later, in connection with this battery-commander station, a plotting room was constructed farther down in the rear slope of the central traverse, as will be described hereafter.

Within the next year or so somewhat similar battery-commander stations were built at several of the older mortar batteries, one of which is described in the twenty-third supplement to mimeograph 42, issued in 1906. This mimeograph shows designs for a concrete battery-commander station for mortar batteries. The station is about 6 feet wide by 10 feet deep, has reinforced concrete walls and roof, and the usual observation slots. No battery-commander walk was provided, as the conditions did not permit it, nor was a plotting room built in connection with the battery-commander station.

A few years later the writer, then the district officer at Honolulu, designed an improved battery-commander station and plotting room for the mortar battery then under construction for the defenses of Honolulu. The battery was of the 1906 type of mortar battery. (Plate XXVIII.) The plotting room was built just over the roof of the rooms in the central traverse and near the rear of that traverse. The battery-commander station was placed over the front end of the plotting room and was provided with a reinforced concrete roof and observation slots. No battery-commander walk was built, because a fairly good view of the pits could be obtained from the battery-commander station. However, to enable an officer to quickly get down closer to the pits, short flights of steps were provided from the door of the plotting room down to the roofs of the alcoves of that room. These alcoves had been added to the plotting room to take care of the shafts of the mechanical data indicators and extended from the side walls of the plotting room diagonally sideways and backward until they overhung slightly the side walls of the mortar pits. It was therefore possible for a person upon the roof of one of these alcoves to walk out until he was practically over the edge of the pit.

In 1913 and 1914 battery commanders' stations of two different types were built at the two tactical batteries of eight mortars each into which the original Fort Monroe mortar battery had been divided. It was at one of these batteries that there had been built the original experimental battery-commander station described a few paragraphs above, and just below it had been built the plotting room. The plotting room was constructed of plaster upon metal lathing. It had been gradually knocked to pieces by the effect of the blast and needed to be replaced. Consequently, at this battery a new concrete plotting room was built, located, like its predecessor, in the rear slope of the central traverse of the battery. Over the front part of this plotting room was built the new battery-commander station, which was quite similar to the original experimental one, having concrete walls on three sides and a door to the rear. No roof was provided, and a removable frame for stretching a canvas awning was added over it. The roof of the plotting room in rear of the battery commander's station was utilized as a sort of battery commander's platform and was extended toward each flank by a concrete walk which led out far enough to enable the battery commander from its end to see into the pit.

A hole was cut in the floor of the battery commander's station, and over it was stretched a thick wire grating. This, in turn, was covered by a removable cast-iron cover. By raising the cover it was possible for the battery commander in his station to see through the grating what was going on in the plotting room and to talk to the detachment working therein.

The battery commander station and plotting room at the other tactical half of the original large mortar battery was a little more elaborate but of the same general character. The plotting room, instead of being 15 feet square, was made 18 feet square, and the battery commander station was enlarged from 6 by 7½ feet to 7½ by 11 feet. This battery commander station, like the other, was not provided with a roof, an awning frame being provided instead. In one important respect this station differed from the other—its floor was made on two levels. The upper or front level was made 4 by 7½ feet and contained a pier for the battery commander's instrument. The other level, about 4 feet lower and connected with the upper level by steps, occupied the remaining space of the station, and on this lower level were placed the telephone terminals, so that the men at the telephone would be somewhat protected and would not be likely to have their attention distracted by the sight of what was going on in the field of fire.

As in the other station, the roof of the rear of the plotting room was utilized as a battery commander platform, and a battery commander walk was extended in both directions toward the pits. This walk, of course, was too low to permit a person standing on it to see over the mortar battery, and it was therefore considered necessary at each end of this walk to build up a pulpit to the same height as the floor of the battery commander station. On each of these pulpits there was installed a pedestal for a telescope.

The battery commander station just described was the first one to include the two-level idea, which has since been adopted as the standard for battery commander stations for both mortar and direct-fire batteries. (See Plates XXI, XXVI, and XXIX.)

All the mortar batteries built within the last few years, either in the Canal Zone or elsewhere, have been located in ravines or behind hills, from which no view of the field of fire can be obtained, consequently battery commander stations provided at the batteries would have been useless. It was necessary, therefore, to build for the use of the battery commander and at a distance from the battery a station somewhat similar to the ordinary fire-control observing station, which will hereafter be described. Moreover, it was considered necessary to provide at the battery itself a convenient location from which the officer in actual command might supervise what is going on. Consequently, the roof of the plotting house (see Sheet XXIX) has been finished off as a sort of a platform for the battery commander.

The plotting house has its floor about on the same level as the floors of the pits and is located behind the central traverse. The roof of this house has been surrounded by handrails, and stairways have been built leading up to it. From this roof the battery commander, or such other officer as may be on duty, can readily see what is going on in the pits, and by the use of a megaphone can give commands and instructions to the men there; by the use of the voice tubes he can communicate with the detachment in the plotting rooms below him; by means of speaking tubes he can talk to members of the detachment in the magazines and storerooms; and by going to either of the front corners of his platform he can see exactly what information is being displayed for the guidance of the men in the pit. For his protection from the sun or rain an awning has been provided which can be put up or be taken down, as he may desire.

PLOTTING ROOMS.

In the early nineties, at the time when the first modern batteries were under construction, and when fire control, or, as it was then called, "position finding," was beginning to be developed, it was planned that the plotting of the path of the target should be done in a room situated in a thoroughly protected position within one of the emplacements of the battery. At that time the determination of the position of the target with reference to the ends of the base line was called "locating" the target, and the adjustment of this data to suit the position of any particular gun was known as "relocating." Consequently, the earlier emplacement designs show rooms marked "Relocating rooms." (See Plates XIV, XV, XVIII, and XIX.)

As has been stated previously, the interior rooms of most of these old batteries were damp and disagreeable. Furthermore, the noise made by firing the guns, the rumbling of the loaded trucks on the platforms, and the rattling of the chains and trolleys used in projectile service all tended to produce confusion in these relocating rooms. It was therefore decided, at least in time of peace, to abandon the use of these rooms and to do the plotting elsewhere. A move was made to some conveniently located existing building or to some frame structure specially built for the purpose and located usually in the rear of and close to the battery.

However, at about the same time as the plotting boards were being removed from the relocating rooms of the batteries to other temporary but more comfortable locations, the first depression position-finding instruments were under test. In the first form of this instrument the plotting was done upon a map attached to the extended front part of a large and unwieldly base upon which the instrument was mounted. This, however, was soon found to be somewhat awkward, and it was then arranged that the plotting should be done upon a separate board in the same room as the instrument.

The original towers built for the use with the depression position-finding instrument were designed with a view of doing the plotting at the base of the instrument, and but one room was provided at the top of the tower. Later, the attempt was made to do the plotting upon a separate plotting board in the same room, but as it was found that the room was too small for doing this conveniently, all subsequent towers were built with two-story houses at their tops, the idea being that the plotting should be done in a room one story below the observing room.

The designs for such a tower are shown in mimeograph 42, where it will be noted that the upper story or instrumental room forms a sort of loft over the center part of the plotting room on the lower story, the floor of the upper story not extending over all of the lower story. Communication by talking between one story and the other can easily be held. The plotting room was about 15 feet square, but the large instrumental pier passed through its center so that the plotting board had to be placed in a corner.

As has been stated before, the first towers that were built soon proved to be too conspicuous and the attempts to use lower stations having shown the impracticability of relying upon the vertical base system for low sites, there was, about 1903, a return to the horizontal base system and new designs for stations for use with this system were, in 1903, published in the sixth supplement to Mimeograph 42.

The use of the towers having shown the desirability of having a plotting board located close to at least one observing station, the same arrangement was carried out in the new system, one of the pair of observing stations at the end of a base line being made quite large, about 30 by 16 feet, so as to contain in the front part an observing room and in the rear a plotting room. The other end of the base line was occupied as the site of a so-called "secondary" station, which was made merely large enough to contain the azimuth instrument. The usual size of the secondary station was 10 by 10 feet, though sometimes it was made even slightly smaller.

The first instruments that were used in these horizontal base stations were those that had been designed and purchased with a view to use with the vertical base system. In order not to waste the use of the depression principle, for which the instruments were designed, an attempt was made to keep the instrumental height of the stations as close as possible to 40 feet, so that the depression principle of range finding could be used for identification purposes. Where placing these instruments at 40 feet made them too conspicuous, it was said to be permissible to reduce the height to 35 feet, or even in some cases to 32 feet in locations where the range of the target was limited.

Barrancas System.

The successful working of any one base line of a horizontal position-finding system requires that both the observation stations of this base line should remain intact and that the telephone communication between both the stations and the plotting room should not be broken. The stations themselves, if they can be seen, will not improbably be selected as targets by the enemy and the communicating cables, even though placed in underground conduits, may be injured by the enemy's fire. Consequently, the entire system possesses considerable vulnerability.

It was thought possible that it might occur in action that one of the stations of one base line might be put out of commission during action, or that its communications might be cut, and in order that the gun itself might still receive data which could be used, it was proposed that the communication lines should be so designed that the data pertaining to any one base line could be sent to and be used by the plotting rooms of other guns than its own.

It was planned, therefore, that all the communicating telephone cables should pass through a central telephone switchboard room, and that there should be installed in this room a somewhat complicated set of switchboards so designed as to permit the data coming from the base line of any battery to be sent, not only to the plotting room of that battery but in addition to be duplicated in other plotting rooms.

Now, in order that the data coming from any base line may be available for plotting on any plotting board, it is essential that the base line should be equal in length and should have the same azimuth as the base line for which the plotting board was designed.

To render possible the use of an interchangeable set of base lines, it was essential that these base lines be equal and parallel, and, furthermore, in order to avoid too great relocation errors, it was essential that the primary stations of these base lines be grouped fairly close together.

This system was invented by Maj. Whistler of the Coast Artillery, and as the first set of experimental stations was built at Fort Barrancas, Pensacola Harbor, Fla., the system became known as the "Barrancas system." This system consisted of a row of primary station with their instrumental piers on a straight line and from about 16 to 50 feet apart. The secondary stations were likewise grouped in a parallel line and with their instrumental piers at the same distance apart.

Although based upon the idea of making the system less vulnerable by the interchangeability of base lines, it became apparent soon after these groups of stations were completed that this system was itself quite vulnerable, since the comparatively close grouping of the stations pertaining to different base lines made it not improbable that more than one station would be destroyed at a single time. Especially was this true in connection with the first sets of stations which were built entirely of wood.

Furthermore, any one base line can cover satisfactorily but a comparatively limited field of fire and is, therefore, thoroughly suitable only for guns having essentially the same field of fire as its stations have field of view. The different batteries in a harbor seldom cover exactly the same areas, and it seldom happens, therefore, that a single base line is very well suited for the use of more than one or two batteries. So when the attempt was made to adapt the Barrancas system of equal and parallel base lines to our different seacoast fortifications, and to select sites for the observation stations, it was found not to be adaptable to very many locations. The system was later abandoned and subsequent layouts have been based upon the idea of selecting for any particular battery of guns the base line best suited for the field of fire covered by the guns and, in general, to make the selection of sites for base end stations without regard to their suitability for the use of other guns or their relation to the base lines to be used for other guns.

As was noted in the discussion of battery commander's stations, the grouping of the plotting rooms in the primary stations of the Barrancas system had another purpose in view, that of making it possible for the fire commander to go into any of the plotting rooms of the batteries of his fire command and to personally oversee the plotting carried on in these different plotting rooms.

When, however, the close grouping of the primary stations was done away with there was no longer any reason for keeping the plotting rooms at the primary stations, and since with the abandonment of the Barrancas system, the battery commanders were moved back to the batteries, it began to be considered desirable to move the plotting rooms also. This was accordingly done, beginning with the experimental plotting room of Battery Parrott at Fort Monroe, described above.

From this historical sketch of the peregrinations of the plotting rooms, and incidentally of the battery commander's stations, it is seen that they both started at the battery; that they were both moved away to the so-called primary stations; and that eventually both came back to the battery again. This is a curious example of how things sometimes go all around the circle only to come back to the place from which they started.

The relocating rooms of the earlier batteries were usually about 8 by 12 feet and in some cases even smaller, and the earlier temporary stations built in rear of battery for relocating or plotting purposes were no larger. By the time, however, of the development of the Barrancas system, the plotting system had become somewhat complicated. There was in each plotting room not only the plotting board, but the corrector boards for azimuth and elevation, a map case, and other furniture. To provide space for all this it became necessary to increase the size of the plotting room to not less than 15 by 16 feet which has since become the standard. More recently, however, it has become necessary to slightly lengthen the plotting rooms in order to accommodate in one end of the room a mechanical indicating apparatus for transmitting data to the guns.

Plotting Room at Mortar Batteries.

As was stated a few paragraphs before, in describing the experimental battery commander station constructed about 1905 at the Fort Monroe mortar battery, a plotting room was built for that battery farther down the rear slope of the central traverse. This plotting room was set into the rear slope of the traverse. It was entered by a stairway coming up the slope from the rear, and in the front of the plotting room the stairway was continued up to the battery commander's station. The first station, built of timber, was soon injured by blast effects and was very shortly replaced by a similar and slightly larger room built of cement plaster construction, as was then standard. This structure also was seriously injured within a few years and as has been stated was, about 1913, replaced by a concrete structure set well into the traverse and described a few pages above. From this plotting room, in all its various stages, attempts were made to operate mechanical indicating apparatus for displaying in the pits the data for aiming.

The general idea of the first plotting room at the Fort Monroe mortar battery was copied and improved upon in the designs of the mortar batteries built in the Hawaiian Islands. The plotting rooms there constructed were made of concrete and were set well into the rear end of the central traverse at an elevation well above the floors of the pits. From the side walls of the plotting room small alcoves extended out to the flank and obliquely to the rear, and in these alcoves were installed the shafts of the mechanical indicating apparatus which displayed the data through slots at the ends. The alcoves extended over the rear corners of the central traverse and were so turned as to directly face the pits. They were so high in the air as to be easily seen from any point in the pit without the line of sight being interfered with by other persons or by the mortars.

In connection with the design of the Panama type of mortar batteries (see Plate XXIX) a regular plotting house was provided immediately in the rear of the central traverse of the battery. The interior of this house is about 16 by 32 feet; that is, about twice the size of the regular plotting room, so as to accommodate the plotting boards, one for each pit. It thus permits the two pits to be handled tactically as if they were different batteries. In front this plotting room is extended toward either flank in the form of an alcove for the mechanical indicating apparatus which displays data in a turret over this alcove at such an elevation as to be seen from any portion of the pits. In the plotting houses so far built no partitions have been used to separate the two parts of the plotting rooms, but should it ever be desired such partitions could be easily built.

As has been stated, the roofs of these buildings have been prepared so as to make convenient stations for the officer in immediate command of the work of the batteries.

It is customary for the Engineer Department to provide for all plotting rooms, seats or benches around the plotting boards, arrangements for hanging on the walls the corrector boards and other fire-control apparatus, hooks for hanging up hats and coats, a locker or cupboard for keeping maps, and a folding shelf or table upon which the maps and drawings may be spread out for examination.

PLOTTING BOARDS.

In the preceding parts of this chapter an outline has been given of the principles underlying both the horizontal and vertical position-finding systems and of the methods of graphically plotting the observations made on the target by the telescopes at the observing stations. The first plotting boards used were rectangular in shape and were usually of home-made manufacture. As they developed, however, and became more delicate, more careful construction became necessary, and their manufacture and issue was made a function of the Ordnance Department.

The plotting boards gradually increased in complexity and soon there were several types in use. However, by the time of the joint Army and Navy maneuvers of 1905 there had been developed a standard form of board known as the "Whistler-Hearn" plotting board, after its inventors, Maj. Whistler and Capt. Hearn of the Coast Artillery. This board was the first to make use of the principle of parallelism previously described. In size and shape it consists essentially of a segment, slightly more than 180° of a circle, having a diameter of about 5 feet. Carefully made notches indicating the degrees are placed around its circumference and the ends of the plotting bars are fitted with wedge-shaped pieces which slip into the notches of the board. The fractional parts of a degree are set off by means of micrometers on the ends of the plotting bars.

The earlier of these plotting boards were fitted for use with one particular base line only. Subsequently improvements were made so that by inserting a connecting arm of the proper length any plotting board can be quickly adjusted to any length of base line.

The field of view which can be satisfactorily covered by any one base line is, of course, considerably less than a half circle, because as points approach the ends of the base line prolonged the angle subtended at the target by the base line becomes less and less; and when plotting is attempted the intersection of the lines from the two base ends becomes very acute. Consequently any base line is available for use only in a sector covering not more than about 160° of azimuth arc from the center of the base line, and the same limited area is about all that can be satisfactorily plotted with the normal form of plotting board. For observation in other directions auxiliary base lines are usually necessary. With the form of plotting board first used additional plotting boards were needed, one for use with each of the auxiliary base lines. However, there was afterwards developed a form of plotting board which could be modified when necessary so as to permit plotting throughout the 360° of azimuth arc.

The correctness of the plotting as done by pins and strings on the original crude plotting boards, or by bars with the later Whistler-Hearn plotting boards, is dependent upon the correct reading of the azimuths indicated by the scales on the observing instruments which are kept trained on a moving target and are therefore in motion, upon the correct transmission by telephone of the azimuth readings thus obtained, and upon the correct setting of the azimuth strings or bars on the plotting board. In all of these steps errors are possible, and though with skilled observers the chance of making errors is small and any errors made will probably not be large, yet they are still possible. It would appear that a number of these sources of error would be avoided if these plotting bars could by mechanical or electrical means be kept always parallel to the lines of sight of the corresponding observing instruments.

This idea is not new. In fact, more than 30 years ago the Engineer School at Willets Point obtained from England a mechanical apparatus for doing this very thing. It had been invented for use in submarine mining at a time when experiments were in progress having in view the development of a system of submarine mining which would make it possible, from the shore, to explode any particular mine whenever desired. The effective use of this method of firing submarine mines necessarily required that the course of the enemy's vessel through the mined field should be carefully followed on a map upon which were indicated the positions of the mines.

With the apparatus referred to, the map was placed upon an extended base in front of one of the observing instruments. Attached to the instrument and moving with it in azimuth was a ruler, so fastened to the telescope that the edge of the ruler would always be parallel with and exactly below the line of sight of the telescope. At another point on this board—that is, the point corresponding to the location of the secondary base-end station—there was pivoted another ruler. This ruler was so connected electrically with the observing instrument at the secondary station as supposedly to be kept always parallel to the line of sight of the telescope at that station. Electric machinery at that time had not been very well developed, and in actual practice the secondary ruler moved by jerks and jumps and was seldom even approximately parallel to the line of sight of the telescope. The instrument, therefore, although beautiful in theory would not work very well in practice and its use was abandoned.

Comparatively recently, that is, during the last year of the recent war, the same idea was revived for use in connection with the plotting of the movements of aircraft. In this case the plotting is done upon the upper surface of a plate of slightly translucent glass. Instead of using intersecting rulers, the plotting is done by means of the intersection of two well-defined beams of light that are thrown along the undersurface of this glass plate. These beams are pivoted at the two points corresponding to the positions of the observing stations. They are rotated electrically by an apparatus that is supposed to keep them always parallel to the lines of sight of the observing instruments, and since the light beams are without mass and therefore have no inertia it is easier to keep them up to exact parallelism with the axes of the telescopes than is the case with material bars or rulers. As far as is known to the writer at the present time, this instrument has not passed beyond the experimental stage, but the writer is assured that the results of the first experiments have been decidedly promising.

Should this system be shown to be practicable it will do away with a number of the complications of the present system of plotting and will avoid several sources of error.

The Whistler-Hearn plotting board was designed with the idea of using in plotting a scale of 1 to 18,000, that is, 500 yards to the inch. The standard size of board was fixed at that which would permit plotting with this scale up to distances of slightly more than 12,000 yards, which at that time was considered as about the maximum range at which it was probable that seacoast guns would be fired. When, some six or eight years later, it was considered desirable to increase ranges to about 20,000 yards, it was thought that the same plotting boards could still be used by changing the scale to 1 in 36,000, that is, to 1,000 yards to the inch.

Even when the ranges were supposed to be limited to 12,000 yards it was found that in order to make the plotting fairly accurate the base line had to be from 2,200 feet to 2,500 feet in length. When the possible ranges were supposed to be increased to 20,000 yards, 4,000 feet had to be looked upon as the proper length of base line, with a minimum length of about 3,500 feet. Wherever it has become necessary to lay out base lines of lengths approaching the figures just given, great difficulty has usually been met with in finding suitable sites; and, what is more, the sites that are available have not infrequently been so placed with reference to each other and to the field of fire as to make errors of identification of the target not improbable.

Events in the World War have shown the necessity of giving consideration to much greater ranges still, up to 35,000 or possibly 40,000 yards. The problem of position finding at these ranges is one for which, up to the present time, no satisfactory solution has been found. The base lines would have to be at least 3,000 yards in length. In order to be able to see the hull of a target 35,000 yards distant, the observer, even in clear weather, would have to be considerably more than 200 feet above sea level and such high sites are usually not available on our sea shores. From stations as high as are available, with the conditions of low visibility which ordinarily exist along our sea shores, the masts and funnels only of the ships will be in sight, and they will usually be seen but dimly.

Position-finding under these conditions and at such distant targets is almost certain to be unsatisfactory. No assistance in the identification of targets can be given by the depression principle and the observation of the results of fire will usually be impracticable from the shore. It would therefore appear that it will be necessary, for finding the position of such distant targets and controlling fire on them, to rely upon some form of aircraft.

For long-range fire on shore where the targets are fixed, aircraft control of artillery fire is understood to have been very satisfactory, but this does not necessarily prove that aircraft will be very successful in the control of fire at sea where the targets themselves are in motion and where there is nothing fixed which can give the observer in an airplane any certain information as to the speed of the target. Consequently, it is thought probable that at these extreme ranges accuracy of fire will be found to be unobtainable. If that be the case, material damage to an enemy's vessels will occur but seldom, and the effect of fire upon him, if any, will be more moral than material.

FIRE-CONTROL BUILDINGS.

The buildings usually provided by the Engineer Department for fire-control purposes are the observing stations, plotting rooms, battery commanders' stations, fire commanders' stations, battle commanders' stations, switchboard rooms, meteorological stations, signal and radio stations, dormitories, and occasionally power houses.

Observing Stations.

The first system of position finding used was the horizontal system. The observing station was at first extremely simple, consisting of but little more than a pier upon which could be mounted the observing instrument, which was a mere transit or simple azimuth instrument. To a neighboring post were led a pair of telephone wires to which a portable telephone could be attached.

These stations were placed in the open and in positions from which good views could be obtained of the fields of fire of the guns. No houses or other fixed protections were provided and when necessary, the observer protected himself and his instrument from the sun or rain by using a large umbrella similar to those in frequent use by surveyors. When not occupied, such stations were not protected in any way. Consequently, all the instruments had to be portable and were taken away by the detachment when the drill was over.

The next step was to provide over these stations small houses which could be locked up so that the instruments could be left in the stations even when not in use. The stations were usually built of wood and were fitted with wide observation slots through which the telescopes could look.

The next important step in the development of observing stations was taken about 1900, in connection with the vertical base position-finding system. It consisted in the erection of tall towers. One or two experimental towers were built first of different materials, but before long a tower composed of metal framework became the standard. (The Board of Engineers' designs for such a tower are published as mimeograph 42.)

On the first one or two experimental towers, the houses at the tops were made but one story high, but on all of the subsequent towers and on the mimeograph designs the houses were all two stories high. The lower story of the house consisted of the plotting room, about 15 feet square, in one corner of which was placed a steel column for mounting a small azimuth instrument. The observing room was a sort of loft over the center of the plotting room. In the center of the observing room the depression position instrument was mounted upon a concrete pier running all the way down to the ground and not connected at any point with the metal framework or with any portion of the buidling. This concrete column was protected from the wind by an outside metal cylinder forming part of the metallic frame work of the tower, but nowhere touching the concrete column. This was done in order that the vibrations in the tower or house, due to the wind or other causes, might not be communicated to the pier and thus to the instrument.

The mimeograph drawings show the telescopic height to be about 46 feet above the base of the tower or about 50 feet above the ground on which the tower was built. Usually an effort was made to increase the height of the tower or to so locate it that the telescope would be not less than 60 feet above sea level.

In nearly all cases, the houses at the tops of the towers were built of timber and for convenient lighting were covered with a slanting roof of painted wire glass. Observation slots were provided at the proper height around all four walls of the observing room, while around the plotting room somewhat similar windows were provided for ventilation as well as for observation. The houses were reached by metal stairs built partly within and partly without the metal framework of the tower.

The next type of station generally introduced was developed in 1903 for use in connection with the Barrancas system. The plans for this type of station were published in the sixth supplement to mimeograph 42. The Barrancas system was based upon the horizontal position-finding system, there being for each base line a primary station and a secondary station. The instruments to be used in the stations were those that had been purchased for use with the vertical base position-finding system, and for this reason it was considered desirable to keep the instrument heights of these stations up to at least 32 feet and to 40 feet if possible. As most of the localities where the stations were to be built were low, the typical designs show the primary and secondary stations as three-story houses, although, of course, where they were to be built on higher sites, only as many stories as were necessary were to be provided.

The secondary station was a small frame structure about 10 feet square with a stairway on the outside. The upper story was the observing room. The instrumental pier was built of concrete and went all the way down to and into the ground. No part of the house was allowed to touch this pier. On account of the small size of the rooms of the first and second stories, and the fact that the instrumental pier went through them, these rooms were of but little use though they were occasionally used as storerooms.

The primary stations were larger, being in plan about 16 by 29 feet. The important story of the building was, of course, the upper one and this was built on two levels. The upper level, which was in front, contained the observing room with the instrumental pier, while the lower level in rear consisted of the plotting room, about 15 by 16 feet, with its floor at an elevation about 5 feet lower than the floor of the observing room. The two floors were connected by a suitable stairway. The main reason for lowering the floor of the plotting room below the floor of the observing room was in order to permit observation from the observing room in all directions, to the rear as well as to the front. The story or stories below the plotting room were used as dormitories or storerooms.

In the original mimeograph design the stairway from the ground to the upper stories is shown as built on the outside of the building, and this was the method of construction actually adopted in the greater number of stations of this type now in existence. However, it was found that in snowy or sleety weather, men using the outside staircase, especially when going between the dormitory and plotting room, were apt to track into these rooms water and dirt, and consequently mimeograph directions were given that thereafter the stairway between the different stories should be built inside of the structures and not outside. (Nineteenth supplement to mimeograph No. 42.)

In the primary stations of this character which were first constructed, the roofs over the plotting rooms were made of tin in order that they might be very flat. It was discovered, however that in a heavy rain the noise of the rain falling on a tin roof is so great as to interfere with plotting. It was, therefore, prescribed that thereafter the roof should be made of tar and gravel because the rain falling on such roofs makes much less noise than when the roof is of tin.

The first crude observing stations had been built of timber because of its cheapness. The houses at the top of the towers were likewise of frame construction. The Barrancas system was developed at Fort Barrancas in Pensacola Harbor, a locality noted for its good and abundant timber. Consequently these stations also were naturally built of that material, and when the system was extended to other communities the stations there also were usually built of timber.

All frame structures are, of course, subject to destruction by fire, but the fire risk in single isolated frame structures is not very great. Fires are not allowed in the stations and the members of the detachment are not permitted to smoke in them. Incidentally, also, the destruction in a small frame building when struck by an enemy's shell is likely to be no greater than in a similar building constructed of any other material.

When, however, the stations are built in groups as required by the Barrancas system, the fire risk is much increased, since it becomes quite probable that if one station should catch fire several others also will be destroyed.

It therefore became evidently desirable to construct stations, especially when grouped together, of noninflammable materials. Of the several experimental stations built at different places of such materials, that developed in Portland, Me., upon the suggestion of Capt. Sewell, Corps of Engineers, under the direction of Maj. William M. Black, now major general, Chief of Engineers, was the most satisfactory, and the type of construction there developed soon became the standard. This type of construction (see Mimeograph 100) consists of using timber studding for the framework of the building. The walls are composed of cement plaster laid upon metal laths or expanded metal nailed to the studding. In a few cases only the outside surface of the structure was plastered, but generally the inside was plastered also. The roofs of these structures were, as a rule, composed of tin laid upon a timber framework and sheathing.

Structures of this type proved to be exceedingly durable if properly built. When not too near the guns they stood the effects of blast fairly well. Consequently this method of construction soon became the standard, not only for observing stations, but for switchboard rooms, power houses, and many other small fortification structures.

In the fortifications of New York Harbor, many of the observing stations were built of brick, the plotting rooms being lined with white, faced brick so as to make the illumination easier. In several other places quite elaborate structures were built, sometimes of reinforced concrete. But in the large majority of fire-control stations built the plastered type of construction was used.

Most of the sites of the observing stations built in connection with the Panama fortifications were located on hills, and in order to give as much protection as possible and to conceal the stations, the walls and floors were usually built of concrete and set down about 4 or 5 feet into the ground. In designing these half-sunken stations, an important question that came up was whether or not the stations should be roofed; and, if so, what kind of roof should be provided.

An open station lends itself readily to concealment, especially if it is well sunken in the ground, but it exposes the detachment, and incidentally the instruments in the station, to the sun and rain. Furthermore, it is practically impossible to lock up an open station so that when it is not occupied the instruments or fittings are protected from theft or damage by casual or unauthorized visitors.

On the other hand, a roof over an observation station has a tendency to make it conspicuous. In order that observing may be possible, nothing in front may rise above the level of the telescope. Some head room above the instrument must be provided for the observer, and the roof, of course, must project above this. Consequently a covered station is bound to be more or less conspicuous and may draw fire, or may be used as an aiming point for fire directed at the guns.

The details of the Panama observing stations, especially the question of roofs, were frequently talked over by the designing engineer, who is the author of these notes, with the Chief of Coast Artillery and his assistants. Finally, as a result of these consultations, it was decided that where stations were to be constructed in close proximity to the batteries and where their concealment was therefore most essential, a sort of compromise should be adopted. For peace conditions a roof was to be provided over the station, but the roof was to be so designed that by the removal of a few bolts it might be reduced to sections of a size and weight capable of being handled by one or two men. In this way, the roof may quickly be removed and replaced. It was intended that the detachment should be drilled occasionally in removing and replacing the roof. Whether or not this is done is not known to the writer.

These removable roofs provide shelter during peace time to the personnel against the very hot tropical sun or the very hard tropical rains. In addition, they permit these stations during the intervals between drills to be safely closed and locked. When the time for action comes, however, the roofs can be quickly removed and there will remain nothing conspicuous enough to attract the attention of the enemy or to draw his fire.

Although, in general, the Panama fire-control observing stations built in fairly close proximity to the batteries were designed with removable roofs, those stations located where concealment could be easily provided were provided with fixed splinter-proof concrete roofs. In many cases these concrete roofs were covered over with earth upon which it was intended that the growth of vegetation should be encouraged, in order to make the stations blend in with the appearance of the surroundings and thus serve to more effectively camouflage them.

Observing stations constructed within the last few years at places other than at Panama have been built in this same general manner, special emphasis in all cases being laid upon the concealment of the positions of the stations. In some cases where the stations lookout from the face of a bluff, the observation slots have been fitted with removable covers composed of sheet tin. This tin was first placed over the face of the bluff and hammered until it was just about as rough as this face. It was then painted in splotches of the same general color as the bluff and before the paint was dry it was sprinkled with powder formed by grinding up stone taken from the face of the bluff. Consequently in roughness and color these observation slots appear in every way to resemble the bluff. In other places, where stations were built on low sites in the midst of vegetation, care was taken not to injure the vegetation and the art of camouflage was called upon to conceal not only the position but if possible the very existence of the station.

In all observing stations the engineer department always provides benches around the telescope for the comfort of the observer, and such map lockers and shelves as may be necessary.

For comfort in cold weather it is, of course, customary to provide heat, usually by small oil stoves in the plotting rooms. The same thing was sometimes tried in the observing rooms. For observation, however, the windows of the slots must be open, and if this is done when the temperature of the observing room is much above that on the outside, the heated air escaping through the observation windows causes the air to appear to boil when the attempt is made to use the telescope. Consequently, accuracy of observation and heating of the observing rooms are not compatible, and when actual observations have to be made the observing rooms must be left unheated.

In the description given above of the evolution of fire-control stations, the stations described have been those intended for use in connection with the gun fire of batteries. Similar stations have, of course, been used in connection with submarine mining. The main difference between the stations now constructed for battery use and those for submarine mining use is that it is prescribed that the latter shall always be double—that is, in pairs, two primary stations and the two plotting rooms being provided at one end of the base line and two secondary stations at the other.

Observation Slots.

Where uncovered stations are used the line of sight of the telescope passes above the walls of the station. Where roofs were provided over the stations, observation slots or windows had, of course, to be provided on all sides toward which it was expected it might ever be necessary to observe.

For the convenience of the men at the telescope, seats or benches were provided surrounding the instrumental pier and raising the observer to a convenient height for looking through the telescope. (Thirteenth supplement to mimeograph No. 42.) The height of the telescope was fixed, and as far as observation with the telescope alone was concerned, a comparatively narrow observation slot would usually suffice, except where the site of the station was high and it was necessary to observe both distant targets and those at a comparatively short distance away. However, it was soon found to be essential to make these observation slots of such a width that not only could the men at the telescope easily see through them but that men standing on the floor of the observing room could do so also. In order to provide for the difference in height of men, it appeared necessary to make the slots at least 12 inches high, and this was the standard used in nearly all of the first observing stations built. It was found, however, that this made it necessary for extremely tall men to stoop down in order to see out, so it was considered desirable to make the observation slot at least 15 inches high.

Since, in general, a wide field of view is necessary from these stations, it is evident that it is not practicable to provide for opening the observing slots by sliding the sashes horizontally. The attempt was therefore made to hinge them along their upper edge so that they opened inward and upward, being supported when open by chains or hooks from the ceiling. This was found to prevent the taller observers getting very close to the slots and also made it difficult to prevent rain water from leaking in when the slot was closed.

The next attempt was to hinge the sashes on the outside at the lower edge so that the sashes would open outward and downward against brackets provided to support the sashes a little below the horizontal. In general, this worked very well and was the standard for many years. However, when the attempt was made to keep the observation slots open in heavy rains it was found that the rain beating on these open sashes had a tendency to splash into the station. An attempt was made to stop this by building wide eaves to the houses, but it was found to be impracticable to extend the eaves far enough to prevent the splashing.

The next attempt was to hinge the windows on the outside at the top and to raise them upward and outward. A method of doing this mechanically by means of levers and a long shaft operated by chains is shown in the forty-seventh supplement to mimeograph No. 42. This method did not work thoroughly satisfactorily, and finally, in 1908, there was developed by Maj. Chittenden, Corps of Engineers, then the constructing officer in the Seattle district, what is now the standard method of suspending these sashes. Suspended from the eaves of the building are hooks, specially designed so as to catch and hold the sashes when they are pushed open slowly. To release the sashes they are quickly pushed up a little bit higher and are then quickly lowered. (This matter is described in the fiftieth supplement to mimeograph No. 42, and a drawing of the kind of hook intended for this purpose is shown on sheet 2, mimeograph 109.)

This method of suspending the sashes of observation slots has been adopted in practically all recent designs, not only of observing stations but also of battle commanders' stations, fire commanders' stations, etc.

Wiring Slots.

A very convenient improvement adopted in the Panama observing stations, battery commanders' stations, plotting rooms, and other stations, is the so-called "wiring recess." This consists of a recess extending around all sides of the room from 6 to 12 inches above the floor. The recess is 6 inches high, extends some 4 inches into the walls, and is covered by pieces of removable brass plate. The conduits or pipes for bringing in wires end in this recess. The cables or wires are led in the recess around the room, then at the proper place each is led out through a small length of pipe or a notch cut in the wall. (Plate XXI.)

Periscopic Stations.

While the question of roofs for the Panama fire-control station was being discussed with the Chief of Coast Artillery, it was suggested by the writer that if periscopic observing instruments could be developed it might be possible to build an observing station which, while having a concrete roof, would yet not be seen. The periscopic instrument could project through the roof of the station and the roof could be drawn down behind a parapet, leaving visible merely the object end of the instrument, and this would be too small to readily be seen.

Although the periscope as an instrument for observation of a battlefield from a protected position behind a parapet received its first great development in connection with the World War, the principle is not at all new nor in fact is its application to Coast Artillery use.

During the years 1904 and 1905 there was in session in Fort Monroe, Va., a board preparing or revising the Drill Regulations for Seacoast Artillery. Maj. Hamilton Rowan, of the Coast Artillery, was a member of this board. There came up for discussion by the board the question as to whether or not a heavy seacoast gun should be provided with a sighting platform and a sighting telescope. The objection was raised that an observer on the sighting platform would be very much exposed, and to avoid this exposure Maj. Rowan suggested the possibility of using the periscopic principle, so that the observer could stand down on the working platform and do his observing by means of a periscope from that thoroughly protected position. Accordingly, Maj. Rowan supervised the making of a periscope and tried it on the carriage of a 10-inch gun. The first instrument was somewhat crude. It made use of mirrors instead of prisms and had a number of mechanical and optical defects. Consequently, the attempt to use it was a failure and the experiments were unfortunately stopped.

At the time of Maj. Rowan's experiment the use of prisms in telescopes was in its infancy, but this principle has since been greatly developed; to such an extent that at present the erection of images in telescopes and field glasses is accomplished almost exclusively by arrangements of prisms and not by additional lenses. In the standard field glasses used at the present time, the rays of light, after passing through the object glass, pass through a pair of prisms which make two 90° changes of direction in the horizontal plane, so that the rays of light are now proceeding generally toward the object glass. The rays then pass through another pair of prisms which make two more 90° changes of direction, this time in a vetical plane, sending the rays of light once again toward the eyepiece and incidentally forming an image, which is erect. Similarly, the large telescopes now used with the standard azimuth instruments and with the standard depression position-finding instruments, make use of the same principle, having two sets of prisms, both of which change the direction of the rays of light 180°, one set causing an offset in the vertical plane and the other in the horizontal plane.

In other words, the rays of light, after passing through the object glass and proceeding in a general direction toward the eyepiece, are reversed once so as to travel back again toward the object glass, and again a second time so as to travel toward the eyepiece. Incidentally, in these changes of direction, the rays of light at one time make an offset in the horizontal plane, and at another time in the vertical plane. If now, the various lenses and prisms were so placed with reference to one another that all the various offsets and travel in the horizontal direction were made as small as possible, thus concentrating in a vertical direction and travel that may be necessary, nearly all of the focal length of the object glass could be used in vertical travel, and the eyepiece of the telescope could be placed quite a considerable distance below the object glass. The observer could then be located under the shelter of a concrete roof, the telescope projecting through a small hole in this roof and the object glass being above the roof and looking toward the target.

The general principles of such a periscopic observation instrument were suggested by the writer to the Chief of Coast Artillery and to certain representatives of the Ordnance Department at the time when the design of the Panama fortifications was first under consideration. It is understood that an instrument based on these ideas is now about ready for experimental test.

As is to be expected in all new instruments, it is probable that mechanical or optical defects will be found, but it is to be hoped that this time these defects will not cause the matter to be dropped. The writer of these notes is confident that it is a perfectly possible thing to develop and to manufacture a satisfactory observing instrument making use of the periscopic principle.

Plotting Rooms and Battery Commander Stations.

The designs of these rooms and stations have all been discussed in the earlier parts of this chapter and need not, therefore, be treated here.

Fire Commanders' Stations and Battle Commander Stations.

In its general design, a fire commander's station is a combination of an observing station and of a battery commander station. It is fitted with the regular observing instrument mounted upon its instrumental pier, and with observing slots on as many sides as may be necessary. In addition to a regular observing instrument on its concrete pier, there is usually provided a small iron pipe attached to the floor of the station for holding a smaller telescope or observing instrument. Usually a plotting room is provided for use in connection with the station, and not infrequently there is a secondary station at the other end of a base line.

The most noticeable difference between a fire commander's station and other observing stations is in the provision of telephone booths.

After the abandonment of the Barrancas system and the moving back to the batteries of the battery commanders and the plotting rooms, the fire commanders were left with rather meager communications with their battery commanders, the only communication possible being by the ordinary telephone. This was soon found to be unsatisfactory.

The fire commander has to be kept in close communication with each of his battery commanders and with each of the searchlights under his control. To attempt to keep up this communication through a central telephone station was found to be too slow and unsatisfactory, and it was evident that the fire commander must have a separate and special wire to each battery and each searchlight. To have in the fire commander's station a separate telephone for each one of these lines was found to produce confusion, and it was therefore decided to place the fire commander's end of these individual telephone lines, not in his station proper, but in booths.

For convenience and protection these booths were usually placed on a lower story. For communication with the telephone booths, speaking tubes were introduced between them and the fire commander's room. A separate speaking tube was provided to each booth, and in addition, for use in case it became desirable to give at one time the same orders to all the booths, a common speaking tube connecting with all the booths was introduced. By means of this common speaking tube a person in the fire commander's room can speak to the operators at all the telephones at once.

When a battery commander or a searchlight operator desires to communicate with the fire commander he telephones the information to the man in the telephone booth at the fire commander's station, who, by means of an electric bell or buzzer, calls up the speaking tube operator in the fire commander's room and gives him the message. Communication in the reverse direction is done in the same manner, the individual tubes being used in all cases where but one booth is to be communicated with.

However, in addition to the telephones and tubes just described, the fire commander is usually provided with a special form of telephone fitted with a number of levers or buttons by the proper manipulation of which he can communicate directly with any of his battery commanders or searchlight operators over a separate line that does not pass through the telephone booth.

In general, a battle commander's station does not differ much from a fire commander's station. Telephone booths for communication between the battle commander and the various fire commanders, searchlight station, etc., are necessary, as in the fire commanders' stations.

In a few places the battle commanders' stations have been made somewhat more complicated. One type is shown in the twenty-eighth supplement to mimeograph No. 42. In another case, rooms which, in emergency, may be used as sleeping rooms by the battle commander and the officers of his staff have been built as part of a battle commander's station. In general, however, this has not been done.

Switchboard Rooms.

The first switchboard rooms that were built were introduced in connection with the Barrancas system and they had to be quite large for in them there had to be installed the complicated switchboards required by that system, which were so wired that the data from any pair of base-end stations could be transmitted to any plotting room or to as many plotting rooms as might be desired. Although not now needed for the purpose just mentioned, switchboard rooms are still essential for the operation of the present telephone systems. Incidentally, they also frequently contain the motor generators and storage batteries needed to provide power for the operation of the telephone system.

Sometimes existing older buildings or rooms in them have been utilized as switchboard rooms. Sometimes special houses have been built, but the same method of construction has not at all times been used. Sometimes the switchboard rooms have been built of timber, sometimes of plaster, and sometimes of concrete. Plans of several types of switchboard rooms were published in the twenty-ninth, thirtieth, fortieth, and forty-third supplements to mimeograph No. 42.

In more recently built switchboard rooms it has been found convenient to provide, under the floor of the room, a shallow basement or cellar for handling wires. The electric conduits or ducts are led into this basement, and in the basement the wires or cables can be handled easily and can be led up through openings in the floor to the switchboard room proper at convenient places.

Meteorological Station.

The meteorological station is a small station usually about 12 by 12 feet, located at some fairly high and convenient place. It is used for obtaining data as to the velocity of the wind, its direction, the height of the barometer, the temperature of the air, etc., all of which data are transmitted when needed to the various battle commanders' stations, fire commanders' station, plotting rooms, etc.

Usually the meteorological stations have been located in existing buildings. Frequently an old and abandoned fire-control tower has been used for the purpose. Where a new station has had to be built, the method of construction followed has been the same as was standard at the time and place for the construction of other fire-control structures.

Signal and Radio Stations.

A number of years ago, before it became customary to install radio apparatus on the torpedo planters and on the tugs that towed the targets used in target practice, the need was felt of some convenient method of signaling between the shore and these boats.

Occasionally the attempt was made to direct the boats by a simple system of displaying flags in some conspicuous place. Later a trial was made of signaling by means of a searchlight beam, placing in the beam a mechanical shutter by the opening and closing of which a system of dots and dashes could be sent. In one place, where no searchlight was available, an attempt was made to erect in front of the conspicuous exterior slope of a certain battery, a large mechanical shutter composed of planks which could be turned edgeways or flatways and by means of which signaling dots and dashes could be carried on.

No improvised means of this character, however, proved thoroughly satisfactory and requests were made to the Engineer Department for the erection of special stations fitted for signaling to the torpedo planters and target-towing tugs. One of the first such stations was erected at Fort Monroe.

The principal use of this signal station was with the kinds of communication just mentioned, but it was thought that as the station had to be built for these purposes, it might just as well be arranged so as to be available for other kinds of signaling also. Hampton Roads, on the shores of which Fort Monroe is located, is a favorite rendezvous for our Navy and, consequently, the signal station was arranged so as to be available for signaling between the shore and the ships. Many methods of signaling are used by the Navy, and the shore station was to be so designed that any or all of them might be used.

This station was, therefore, erected in a prominent location not very far from the main wharf and well to the flank of all the batteries, so that though it was very conspicuous, it in no way interfered with the fire of any of the batteries. Not only is the station too far from the batteries to be used as an aiming point by the enemy, but since this kind of signaling is considered as a peace time proposition only, the station can readily be destroyed if it should be thought that its existence during time of war might endanger the defense.

The station consisted of a three-story timber building. In order to protect the first story from dampness its floor was raised about 3 feet above the ground and it was entered by a short flight of steps. For communication between the other stories an exterior staircase was provided, running up three sides of the building and connecting with the roof. The roof, which was made of ordinary sheet tin, was surrounded by a handrailing and in order to protect the tin it was covered by a flooring consisting of narrow planks laid with intervals between them.

This roof was used as a station by men communicating with vessels by wigwag or semaphore flags, or by men attaching or detaching flags to halyards hanging from the long yardarm of a tall mast erected a few feet from the station.

The upper story of the building was fitted as an observing room. Around three sides of it there were inserted observation windows similar to those standard in fire-control stations, and at a convenient point in the room a pipe pier was fastened to the floor and was fitted as a mount for an ordinary telescope. Men on the lookout were to be stationed in this observing room both day and night and it was to be their duty, in addition to exchanging signals with the vessels, to give the post commander notice of the approach or departure of all naval and other vessels, when and where such vessels anchored, and also when they might change anchorage.

The middle story of the building was intended as a dormitory and was fitted for the comfort of the detachment. The lower story contained a lavatory, a toilet, and the rest of the room was used for storage purposes.

By means of this station and the tall mast erected close to it and really forming part of it, it was possible to interchange with the Navy signals in many different ways; by wig-wag flags, by semaphore flags, by the display of flag signals from the yardarm, by the electric Ardois signals, by large semaphores attached to the mast, which could be lighted at night, and in many other ways. Incidentally, also, the station was in close and direct telephone communication with the radio station.

The signal station just described was the first one of the character erected, but it was to a great extent copied in many other seacoast forts, of course with a number of modifications required by local conditions.

When, a few years later, it became customary to fit up the torpedo planters and some of the target-towing tugs with wireless apparatus, communication between the shore and the tugs had, of course, to be carried on by wireless, and this required the erection on the shore of regular wireless stations. Wireless communication is considered as something which it is essential to retain during war, consequently it is important that the masts for supporting the antennae should be erected permanently in inconspicuous places; if possible where they can not be seen from the sea, and in any case where they can not serve as aiming points for directing fire at batteries or other important structures.

The masts themselves and all the aerial apparatus are furnished by the Signal Corps. Generally they have been installed by the garrison, although in a few cases the actual erection of the masts and the rigging up of the antennae have had to be done by the Engineer Department.

The operating houses for the radio system have been built by the Engineer Department. In a few places they have been reinforced concrete structures, but more generally have been of plaster on metal lathing. They have ordinarily been located in positions where ample protection was available.

Dormitories.

Specially constructed dormitories have generally been considered necessary only for isolated groups of fire-control stations. Being intended for war use only, they have been of quite simple construction and no special remarks concerning them appear necessary. Where electric power has been available, dormitories have been wired for electric lights, but in more isolated positions no special means for lighting have been installed, it being intended that reliance should be placed upon ordinary oil lamps.

Power Houses.

Generally, the primary source of power for operating fire-control telephones has been the regular fortification power system; motor generators being used to reduce the voltage to that required by the telephone system. The motor generators required and the storage batteries, when necessary, have usually been placed in one of the so-called "switchboard rooms."

Occasionally, however, special houses for fire control use have been required, and when required have been erected by the Engineer Department. Such stations, however, have been similar, except in size, to the regular power house erected for general fortification use and no general remarks concerning them is necessary.

COMMUNICATION OF DATA.

With any of the systems of position finding as outlined in the earlier parts of this chapter, it is evident that the information that has been obtained must be transmitted from the observing instruments to the plotting room and from the plotting room to the guns. Where the distance is not great, as for instance where the plotting is done in the same room with one of the position-finding telescopes, the information may be transmitted orally either by shouting or by means of a small voice or speaking tube. Where the distance is great, however, information has to be sent by the telegraph, telephone, or telautograph.

All three methods have been used, but of the three, the telephone is the only one that has proved satisfactory. In practice, the observers and the receivers all wear head sets, so that they can speak in a low tone of voice directly into the transmitters. The telephone receivers are held by the head sets close to the ears of the plotters, so that this method of communication is not interfered with by the talking of other persons or by other noises, nor does it interfere with any other conversation that may be carried on at the same time. The telephone is now customarily used, even where the distance through which the data have to be transmitted is but a few feet, since in this way there is no possible source of error as to the source of the exact piece of information which is heard.

Telautograph.

The telautograph is an instrument by which something written at one place is reproduced electrically in a facsimile at another. The pencil used in writing is attached to two cords wound up on two cylinders placed about a foot apart. As the pencil moves these cylinders wind or unwind according to the length of the cords from the cylinders to the pencil. The receiving instrument has a writing pencil connected by rods with two points corresponding to the two positions of the cylinders on the transmitter. By electrical means, as the transmitting cylinders wind or unwind, the rods of the receiving instrument are drawn in or pushed out, so that theoretically the writing done by the receiving pencil is a facsimile of that done by the transmitting pencil.

The use of this instrument for transmitting fire-control data was advocated, because it was feared that just at the time that a member of the gun detachment was receiving information by telephone as to the setting of the gun, the receipt of this information might be interfered with by the noise of the discharge of a neighboring gun, by the rumbling of the ammunition trucks, or some other noise. It appeared well, therefore, to have the information appear before the man in plain sight, so that he would see it as well as hear it.

Many experiments were made in the attempt to adapt the telautograph to seacoast artillery use, but many difficulties were met with, some electrical and some mechanical. The telautographs were at first connected electrically with the regular post electric systems which, at the time, were based on the use of storage batteries. It was soon found out, however, that the fluctuations in the voltage of the terminals of the storage batteries, due to the irregular demands for power in connection with ammunition hoists, caused the telautographs to work most irregularly and badly. The attempt was then made to connect them to the generators, but even the ordinary fluctuations at the dynamos themselves were found to be too great for the successful working of the telautographs. Still further experiments were made, until it finally appeared that the telautograph would work satisfactorily only when it received its power from a storage battery which, for the time being, was used for nothing else. Many of the supplements to Mimeograph 48 treat of this subject and are of considerable interest.

Mechanically, the first telautographs used in gun emplacements were thrown out of adjustment by the shock of firing, at least when attached firmly to the walls of the emplacements. Later they were hung on specially designed springs, and these springs were eventually so well perfected that under the best of conditions the telautographs seemed to work fairly well even when fastened to the gun carriages. However, although the telautographs would work fairly well when under expert supervision, without such expert control they would soon get out of order. It therefore appeared that they were too delicate for general Coast Artillery use and they were ultimately discarded.

Telephone Wires and Cables.

Except in the immediate vicinity of a telephone or in a switchboard room, individual telephone wires are seldom used, cables containing many pairs of wires being preferred.

In the earlier installations, these telephone wires and cables, as well as power cables, were usually strung in the air on poles, but as thus strung they were considered to be somewhat vulnerable and subject to being broken, not only by the direct fire of the enemy's projectiles, but by fragments of exploding projectiles as well. Furthermore, it was feared that under some circumstances they might be easily cut by a malicious person. Consequently, it soon became customary to make the permanent installation of all communication cables in duct systems buried several feet below the surface of the ground. These duct or conduit systems are installed by the Engineer Department and, of course, as the system of communication becomes more and more complex, these duct systems become more and more extensive. These subjects were discussed at some length in the chapter on electrical installations and the discussion need not be repeated here.

MECHANICAL DATA TRANSMISSION.

When the plotting rooms were located at a considerable distance from the batteries, as was generally the case when the towers pertaining to the vertical-base position-finding system were in use, or when the Barrancas system was in vogue, the only proper method of transmitting to the detachment around the gun carriage the data needed for aiming the gun was by telephone. Telephone communication is not always reliable, especially when there is much noise and confusion, and it was in an attempt to remedy this condition that the telautograph was introduced.

About the time that it was finally admitted that the telautograph was unsuited to seacoast artillery work, the plotting rooms were moved back to the batteries and it seemed as if it should be possible, by mechanical means, to transmit the data needed for aiming the gun in a form which should be visible as well as audible.

Mechanical Transmission of Aiming Data at Mortar Batteries.

The mechanical transmission of aiming data seems to have been first attempted in mortar batteries, and this was but natural because it was at mortar batteries that the need of such mechanical transmission was first felt. At a direct fire gun, the azimuth data has to be transmitted to but one man, the elevation data to another, but this can be done most easily by telephones, and head sets can be worn by these two men. In mortar batteries, four mortars have to be set simultaneously and with the same data. With four mortars in a pit and four loading trucks moving around, it was found to be impracticable to have the men setting the mortars wear telephone head sets. It was therefore very desirable that the required data should be displayed at a place where it could be seen by all the men engaged in setting the mortars.

About 1903, there was developed in Portland, Me., a form of so-called "mortar battery booth." Plans of this booth were published in the sixteenth supplement to Mimeograph No. 48, and are shown in outline in figures 5 and 6 on Plate XXVIII. (It should be noted that on this plate the drawings of the booth have been made as if it were viewed by a person in the pit looking at the booth, which is in rear of the pit. This view best illustrates the use of the booth, but makes these drawings an exception to the general rule that in all fortification drawings the top of the sheet should always be the direction toward the enemy.)

As shown on the drawing the booth is a reinforced concrete structure about 7 by 8 feet in plan, with about 6½ feet headroom inside. The walls and ceilings of the building, as well as the sliding metal door, are all made strong enough to stand the effect of the blast and it is therefore possible to locate such booths only a few feet to the rear of a mortar pit. The booth was to be located in rear of the right side of the pit and from the rear of the left side of the booth, which is the side toward the axis of the pit, the aiming data is displayed by chalk figures written upon sliding sections of blackboard. The method of operation is as follows: The sliding blackboards are drawn into the booth, the desired data is written on them, or on as many of them as may be necessary and the boards are then pushed out so as to be visible to the men in the pits. For use at night, these boards are, of course, illuminated by electric lights in shielded hoods not shown on the drawing. In the front left-hand corner of the booth windows are shown by which the men inside can see what is going on in the mortar pit. For these windows, metal frames with thick glass were used, similar to the bull's-eye windows used on shipboard.

The booth was directly connected by telephone with the plotting room. The aiming data, as soon as it was worked up in the plotting room, was transmitted by telephone to the men in the booth who quickly wrote it on the blackboards and then slid them out for the information of the men in the pit. If desired, it was planned that the mortars might be fired from the booth.

It was discovered soon after these booths were built and placed in service that the figures written hurriedly on a blackboard were not always easily legible, at least at the distances from which they had to be viewed. Moreover, blackboards when once wet by heavy rains are somewhat difficult to write upon, and furthermore, the figures written on them may be removed by a driving rain. This type of mortar booth, therefore, although quite widely used, was never thoroughly satisfactory.

At about the same time that this form of booth was being developed at Portland, experiments with the same idea in view were in progress at Fort Monroe in connection with the work of the board on the revision of Seacoast Artillery Drill Regulations. The first experimental work of this character was done on a temporary frame structure that happened to be in rear of one of the pits of the Fort Monroe mortar battery so that changes could be easily made. As a result of these experiments, a new and improved form of mortar booth was evolved and samples were erected in rear of all the pits of this battery.

This Fort Monroe type of mortar booth (not shown in any of the plates) was similar in construction to the Portland booth, above described. It was of approximately the same size, its walls and roof were built of reinforced concrete, and its door was of heavy sheet metal. It differed from the Portland booth, however, in displaying the data on its front and not on the side. Consequently it was placed in rear of the center of the pit instead of in rear of the right side.

In this case the figures or letters were painted on wooden slides moving horizontally and were displayed to the men in the pit through slots cut in a metal plate inserted in the front face of the booth. These slots were so arranged that the figures indicating the degrees and fractions of a degree of azimuth and of elevation read downward, but in order that there might not be any confusion between the two sets of figures, the azimuth and the elevation figures were considerably offset to the side, one from the other, and were plainly distinguished by the letters A and E, painted above them.

The slides with the figures painted on them moved horizontally, and in addition to the figures painted on their front sides which appeared to the men in the pits through the slots, other and smaller figures were painted on the rear sides of the slide and were, therefore, visible to the men in the booth. These figures were so arranged that when any figure, as for instance 3, appeared through a slot to the men in the pit, the figure 3 on the rear of the same slide showed between two vertical bars to the men on the inside. Consequently, the officer or noncommissioned officer in charge of the booth could see at any moment from inside exactly what data was displayed to the men in the pit.

It was in a booth of this type that the plug board for the operation of the zone signal system in the powder magazines was operated.

The first mortar booths built, both of the Portland type and of the Fort Monroe type, were located on the same level as the floor of the pit. Consequently, the sight of the men in the pit whose duties required them to see the data displayed was frequently cut off by persons passing between them and the booth. In fact, the mortars themselves, when aimed at certain azimuths, would frequently cut off the view of the men setting them. Consequently, it soon became evident that data, to be easily seen by men at work at the mortars, must be displayed on a level well above the floor of the pit.

In addition, the types of mortar booth referred to are not suitable for plotting purposes and the aiming data needed had to be transmitted to them by telephone from a plotting room. This, of course, introduced a possible source of error.

Fortunately, it soon became possible to avoid such errors because, very shortly after the first mortar booths were built, the plotting rooms were moved back to the mortar batteries and it became possible to operate the display apparatus directly from the plotting rooms. As has been stated, it was at Fort Monroe that the first experimental plotting rooms were built at mortar batteries, and in connection with them the attempt was made to operate directly from the plotting room elevated data display boards which would show to the men in the pits the aiming data, so high up that their view could not be cut off either by the mortars themselves or by other persons moving around.

The display boards used consisted of iron plates supported by iron framework well up in the air. The data displayed consisted of figures or letters painted on the front sides of vertical metal slides, and appeared through slots as the metal slides were raised or lowered. The slides were moved by means of wires passing around pulleys at the top of the display board and passing thence nearly horizontally through the air to the plotting room, which they entered through openings near the ceiling.

In one form of this display apparatus the single-wire system was used, the metal slide being made heavy and gravity being relied upon to pull it down; in another form, an attempt was made to use the two-wire system; there being, in addition to the wire attached to the top of the slide, another wire passing from the bottom, around a pulley at the bottom of the display board, thence up to another pulley at the top of the board, and thence into the plotting room. In other words, each slide formed part of a continuous wire circuit. Of the two systems the one wire gravity system seemed to work more satisfactorily.

The Fort Monroe mortar battery was of the 1894 type (Plate XXVII), and the experimental plotting room was built on the rear slope of the traverse between two mortar pits. The same data was always displayed to both pits at the same time. Consequently, the wire coming from the slide of one display board in one pit passed through the plotting room and thence to another slide on the display board in the other pit. As the slide in one display board was pulled up, the slide in the other display board went down, but since the figures were painted so as to increase upward on one board and so as to increase downward on the other, the same figures were always displayed at the same time on both boards. This arrangement had the advantage that the corresponding slides on the two boards counterweighted each other and they could be made so heavy as to be certain to always take up all the slack in the wire. As the wire passed through the plotting room it was attached to a slide which, at a proper place, displayed to the persons in the plotting room the same data as was displayed to the men in the pits on the two display boards.

Although, on the whole, this system has worked fairly well, a number of mechanical difficulties have been encountered. In the first place, it was found that the wires had a tendency to continually change their lengths, and consequently it was necessary to place several turn-buckles in each of them and to readjust their lengths at frequent intervals. Again, the wires, when rapidly operated, had a tendency to slip off the pulleys or to get caught in them, and what was worse, in snowy or sleety weather the entire system was apt to be completely frozen up.

Occasionally, also, a slide would stick and would fail to take up all the slack. It might, therefore, display an erroneous number. It was in an effort to overcome this trouble that the attempt was made to use the two-wire system. In this system, each slide, with the wires attached to it, formed a complete loop and if any part of the loop was moved, the whole loop had to move as well. In this double-wire system, however, the changing length of the wires gave even more trouble than in the single-wire system and where it had been tried a return was made to the single-wire system.

In the first of these systems tried at Fort Monroe, the slides in the plotting room were arranged on the rear wall one above another and moved horizontally. In the new plotting rooms installed in 1913 and 1914 the slides were placed on the side walls of the room and moved vertically. This latter method seems to have proved the better.

Still another and quite different type of mechanical data display apparatus was installed in the Honolulu mortar battery completed by the author in 1910. This battery is a two-pit mortar battery of the 1906 type. (See Pl. XXVIII.) The plotting room was built in on the top of the rear of the central traverse. On each side of this plotting room a sort of tunneled alcove was constructed leading out diagonally to the rear and toward the mortar pit. The data display board was placed at the end of the front side of this tunnel directly over the side of the mortar pit and so high up as to be easily visible from all portions of the pit. The data shown consists of figures painted on the cylindrical surfaces of drum-like wheels, displayed through slots cut out at proper places on the display boards. These drums are manipulated by shafts leading from the plotting room and, of course, give indications at the plotting room ends of the shafts of the figures which are displayed at the outer ends to the men in the pits.

Unfortunately, certain mechanical difficulties have developed in this apparatus. In order that the figures displayed to the men in the pit might be of the proper size, the drums had to be quite large and this made them heavy. The shafts, likewise, were quite long and had to be strongly built so that whenever a drum had to be moved there was considerable inertia to overcome, and considerable practice was required in order to properly manipulate the apparatus. An officer interested in the subject should inspect the drawings of this Battery Harlow apparatus.

Some two or three years after the completion of the Honolulu mortar batteries and the installation in them of the mechanical data display apparatus just described, there was developed the 1912, or Panama type, of mortar battery, the outline drawings of which are shown on Plate XXIX. One of the special new features of this type of mortar battery is the plotting house, one such plotting house being built just in rear of the central traverse separating the pits of each tactical mortar battery, which consists of four mortars embraced two in each of two mortar pits.

On the ground floor of the plotting house there is the large double-size plotting room and from each of the front corners of this room there extends out sideways a rectangular alcove about 7 by 8 feet in size and intended for the operation of the mechanical data display apparatus pertaining to the mortar pit on the corresponding side of the traverse.

The data is displayed to the men in the mortar pit through slots cut in the face of a data display plate set in the front wall of a rectangular turret located over the center of the alcove. Measured on the inside, this turret is about 3 by 9 feet in size and its ceiling is about 5 feet above the ceilings of the alcove and plotting room, so that the turret projects up well above the roof of the plotting house. The turret is set somewhat obliquely to the sides of the plotting house, so that a line from the center of the turret and perpendicular to its length passes about over the center of the mortar pit.

The details of the data-indicating apparatus are quite simple and are shown fairly clearly on the inset on the right-hand side of Plate XXIX. Fastened by brackets to the front wall of the turret there is a long horizontal fixed shaft, about which, as upon an axle, there revolve the 10 or 12 display wheels. The rims of these display wheels are about 20 inches in diameter and consist of cylindrical surfaces 3 inches wide and more than 5 feet in circumference. On these cylindrical surfaces are painted the figures or letters which are displayed to the men in the pit through the slots cut at the proper places in the data display plate. This data display plate is tilted slightly to the front so that a line normal to the surface of the plate and passing through its center will about pass through the eyes of a man standing on the pavement at the center of the mortar pit.

Firmly attached to each of the display wheels, and therefore revolving with it, there is a sprocket wheel over which hangs a short length of sprocket chain. From each end of the sprocket chain there hangs a short length of wire or wire rope. The wire rope attached to the rear end of the sprocket chain, that is, the end farthest from the pit, is attached to the upper end of an index slide, while that attached to the front end of the sprocket chain passes down and around a pulley or sheave attached to the floor and thence up to the lower end of the same index slide. At a convenient height there is firmly attached to the front wire a nicely shaped grip, by means of which the operator can cause the index slide to move up and down. This causes the figures on the rim of the display wheel to revolve behind the slot in the data display plate on the front face of the turret. As this index slide is moved up or down in the alcove it passes just behind a horizontal index plate and, through a slot in this plate, the figures or letters painted on the front surface of the index slide appear to the operator. These are so painted that the letter or figure showing to the operator in the alcove through the slot in the index plate is always the same letter or figure that is displayed from the rim of the display wheel through the slot in the data display plate to the men in the pit.

The joints where the wire ropes are attached to the index slide are both made adjustable, so that the circuit of the wires, chain, and index slide can be easily kept at the proper length, and so that the index slide can be placed at just the proper place in the circuit as to indicate properly. Furthermore, and in order to properly balance the circuit and avoid any tendency to move of itself, a counterweight is attached to either the front or rear wire as required.

In order that the circuit may have a tendency to stop at such places as will accurately center the figures in the display slot, there is placed above the axle at the top a small weighted lever with a roller at its end. This rolls around the surface of a star wheel firmly attached to the display wheel. This roller tends to stop the wheel at certain places only, that is, just when some one figure is exactly centered behind the display slot.

The operator in the alcove stands in front of the apparatus with his back to the mortar pit, where he can see into the plotting room. As he receives instructions from the plotting detachment, he manipulates the index slides, and he knows that the data shown to him through the slots in the index plate are always exactly the same as are displayed from the data display plate of the turret to the men in the pit. In order to keep his feet from accidentally getting caught in or injuring the wires or the floor pulleys, a so-called "kick board" is attached to the floor between his feet and the pulleys.

The drawings show 11 complete index slides and circuits, 5 for indicating the degrees and fractions of a degree of azimuth, 4 for the degrees and fractions of a degree of elevation, 1 for the zone, and 1 for the type of projectile. Of course the same system is adaptable to a larger or smaller number of circuits. If it should appear to be advisable, the azimuth figures of the display apparatus could be painted one color, the elevation figures another, etc.

The electric lights for illuminating the data display board at night are indicated in the drawings. The apparatus under the alcove is lighted at night by electric lights which are not shown. For the illumination of this interior apparatus in the day time three bull's-eye windows, not shown on the drawing, are provided. These bull's-eyes are located in the front and side walls of the alcove, and are placed so high up above the floor that they can not readily be used to look out of, so there is no temptation to the operator to permit his attention to be diverted from his proper duties in order to see what is going on in the pit. As the bull's-eye windows are quite exposed to blast, they must be made of specially strong glass such as is used in the portholes of ships.

At some batteries, a hinged shutter was added to the front of the turret so that it could be lowered down in front of the display plate and thus cut off all view of the plate from the pit. Where the shutter has been added, it is intended that it shall normally be left down. The apparatus will be set while invisible from the pit. When all data have been properly set, this shutter will be raised thus displaying them all to the pit at the same moment. When the mortars have been laid, the shutter will be lowered again thus cutting off the view of the display plate.

Mechanical Display Apparatus at Rapid-Fire Batteries.

Very shortly after it was found to be possible to mechanically display aiming data at mortar batteries, the attempt was made to do the same thing at rapid-fire batteries. A concrete booth was built in rear of the center of the battery and the display apparatus was installed above its roof. The apparatus was very simple. The figures were painted on the front face of circular disks. Behind each disk and attached to the same axle was a sprocket wheel. The sprocket chains passed down to a similar disk within the booth. By moving the disks the proper figures were displayed to the men at the guns and the same figures were visible to the men in the booth. The original display apparatus was based upon never having to display a range as great as 10,000 yards. Since no graduations less than 10 yards were used, all that were necessary were three changeable figures and a fixed zero for the unit digit. Consequently the apparatus required but three disks and was exceedingly simple, but if necessary for ranges greater than 10,000 yards, a fourth disk could have been used. One form of the apparatus is illustrated in the fifty-second supplement to mimeograph No. 48.

Mechanical Display Apparatus at Large Gun Emplacements.

Shortly after it became customary to build concrete plotting rooms in rear of the central traverses of heavy gun batteries, as has been previously described, an attempt was made to operate from these plotting rooms mechanical data display boards. In most cases the means employed were horizontal shafts attached by brackets to the rear face of the emplacements, just below the level of the loading platforms and truck corridors and just above the ceilings of the lower story. These shafts were operated by sprocket wheels placed on them immediately in rear of the plotting rooms, the sprocket chains passing up to other sprocket wheels in the plotting rooms.

Immediately in rear of the center of each of the loading platforms, a small display board was built containing drums with figures painted on their cylindrical surface. These appeared through slots to the view of the men on the loading platform. In the larger batteries where the guns were rather far apart, the shafts had to be quite long and consequently possessed considerable inertia. It required a good deal of force to start them rotating, and considerable strength and skill to stop them at exactly the proper place. To obviate this difficulty the attempt was made to do away with the use of shafts and to substitute wires extending all the way from the plotting room to the display apparatus and back again, passing en route over or around as many pulleys as might be necessary. All these wires were made in continuous circuits, but considerable difficulty was met with in trying to keep the circuits at exactly the proper length and in preventing the wires from jumping occasionally off of the pulleys so that, taken as a whole, the display apparatus using wires was not as successful as when shafts were used.

All the types of apparatus just described displayed the data in a box built in rear of and only a few feet above the floor of the loading platform, and therefore in a position such that the men around the gun were extremely likely to have their view of the displayed data cut off by the movements of other men of the detachment. It was evident therefore, that to be more readily usable the data must be displayed in a more convenient place.

In the 1912 type of direct-fire battery (Plates XXIII to XXVI) each gun has its own plotting room. In each emplacement a tunnel was built, starting from a pit cut in the floor of the plotting room and proceeding to a point under the steps connecting the loading and working platforms at a point directly to the left of the gun center, the data being displayed through slots cut in the uppermost of these steps.

Similar arrangements were made in the 6-inch Panama batteries (Plate XII), pits being cut under the floor of the plotting room which served for both the guns of the battery. From these pits under the plotting room, tunnels were dug to the left sides of the loading platforms where the display apparatus was located.

The mechanical apparatus for use in these Panama batteries was quite unique and the detailed drawings should be obtained and studied.

As will be noted, many forms of display apparatus have at times been tried—horizontal slides, vertical slides, shafts, wire, and sprocket wheels, etc. Up to the present time no type of apparatus can be considered as standardized.

Of course, where data are displayed by any of the apparatus mentioned, arrangements have been made for illuminating the display boards at night. This illumination, of course, must be sufficiently powerful to make the letters and figures easily legible but yet must not be so bright as to cast a glare visible to the enemy, or so as to interfere by glare or otherwise with the sight of observers on the sighting platforms of the guns, or in battery commander or range stations. Consequently, all lamps used must be so hooded as to throw their light on display boards and nowhere else.

Electrical Data Transmitters.

Owing to the considerable distances over which the mechanical apparatus for transmitting data had to be extended in some batteries, the difficulties due to the varying lengths of the wires, if wires were used, or to the weight and consequent inertia of the long shafts required, it appeared that a somewhat simpler apparatus might be designed to be operated by electricity. As early as 1905, an experimental attempt was made at Fort Monroe to operate by electrical means a data indicating board. At the display end of this apparatus, the numbers to be displayed to the men in the mortar pit were painted on the peripheries of small drums, and these drums were connected electrically with somewhat similar but smaller drums on the apparatus in the plotting room. As the drums in the plotting room were moved by hand, the drums in the pits were supposed to be operated by electricity so as to move synchronously. At first, when tested without firing the mortars, this apparatus worked quite well, but it appeared to be unable to withstand the shock of firing. Consequently, it was abandoned, but in the opinion of the author this was done much too soon and before the possibilities of the apparatus had been thoroughly tested. Somewhat similar but modified forms of the same apparatus have been tried occasionally since, but none have been successful.

About a year ago another form of electrical indicating apparatus was tried in one of the 1915 type of barbette batteries at Sandy Hook. This apparatus works on exactly the same principle as the display boards frequently installed over the doors of hotels and theaters for displaying the number of carriages which it is desired to call. For each digit to be used, quite a number of electric light bulbs are installed, and by illuminating certain of these lights at a time the desired digit is roughly outlined. By night these figures are easily visible, but the apparatus has been installed so that it can be used by day also, the display boards being placed in shaded black painted recesses. This apparatus has been but recently tested and is understood to have worked very well, but whether or not it will be found to function satisfactorily in service only the future can tell.

TIME-RANGE BOARDS.

In one of the early stages of the development of the fire-control system, the plotting of ranges was to a ceratin extent done on the loading platforms. A blackboard was erected on each loading platform in such a position as to be easily seen by the men at the range wheel of the gun carriage. . On the blackboard were painted in white a series of vertical and horizontal lines which could be numbered at their ends. From time to time, every 20 or 30 seconds as might be decided upon, the calculated range of the target was received by telephone from the plotting room and was promptly plotted upon this time range board, one set of lines being used to indicate ranges, and the other seconds of time. Some 20 or 30 seconds later another range would be received and would be promptly plotted on the blackboard by another dot. After a few dots had thus been made on the time range board, it was easily possible with a ruler to prolong the line of dots across the board, and from this line to roughly predict the range the target would have at any subsequent time.

A few years later, however, after the introduction of the Whistler-Hearn plotting board and its refined apparatus for making all the various corrections that might be necessary, the use of the time range board on the loading platform appeared no longer necessary and it was abandoned.

Still later, shortly after Gen. Weaver became Chief of Coast Artillery, he thought it well to restore the use of the board. At his request, specially constructed time-range boards with mechanical arrangements for easy plotting were made by the Engineer Department and were installed on the loading platforms of the batteries then in existence. As about this time the detailed designs of the Panama batteries were approaching completion, they were modified so as to include the time range boards. In addition, the designs of the mechanical data transmitting apparatus for large guns were modified so that this data, besides being displayed in the steps on the left side of the gun where it could be seen by the men at the range wheel of the gun carriage, would be displayed also in another place where it could be seen by the men working at the time range board.

CHAPTER XIII.

NIGHT ILLUMINATION OF BATTLE FIELDS.

The best and most available method now known of illuminating the battle area in front of a seacoast fort is by means of searchlights. A searchlight or, as it is frequently called, a "projector," consists essentially of a strong electric arc light placed in the focus of a concave reflecting mirror which, by reflection, projects the rays of light falling upon the mirror into a beam composed of rays parallel or nearly parallel, and thus permits the night illumination of distant objects.

The electric arc is dependent for its formation upon a powerful electric current and as long as the only known source of electricity was a galvanic battery, the arc light remained but little more than a laboratory toy. It did not become a practicable apparatus for general use until after the development of electric generators operated by steam engines or other prime movers. Though, for this reason, the electric-arc searchlight is a comparatively modern invention, the night illumination of battle fields is by no means new, specially built fires having at times been used for this purpose since the earliest dawn of history and probably before. Furthermore, in a night assault on one of the forts in Charleston Harbor during the Civil War, Gen. Gilmore (whose regular commission was in the Corps of Engineers) made a fairly successful attempt at battle-field illumination by means of a mirror and what was at that time called a "calcium" light, the light of which comes from a piece of lime heated to incandescence by being placed in an oxyhydrogen flame.

Shortly after the Civil War there was established at Willetts Point, (now Fort Totten, Long Island, New York Harbor), an Engineer school, and as early as 1872 experiments were made at this school with a view to determining the possiblity of using searchlights for seacoast defensive purposes. A few years later, a small searchlight was purchased and shortly thereafter it became customary to have regular night drills with this searchlight for the purpose of tracking vessels moving through a supposedly mined field. The light, however, was a small one and in these night drills no attempt seems to have been made to illuminate targets at a greater distance than from 1,500 to 2,000 yards.

In 1886, in the report of the Endicott Board, the subject of searchlights is referred to and it was recommended that 200 lights be purchased and installed in the seacoast defenses of the United States. Nothing is said as to the way in which this estimate of 200 was obtained.

Although about this time but little was being done in this country, the manufacture of searchlights was developing abroad quite rapidly and, in 1893, as an advertisement, there was exhibited at the Chicago World's Fair a 60-inch searchlight of German manufacture, along with its special generating plant. This searchlight and generator were purchased by the United States, and after the close of the Exposition were sent to the Coast Artillery school at Fort Monroe and installed there.

After the installation of this light, drills and experiments were carried on quite regularly at Fort Monroe as had been done at Fort Totten. With these exceptions but little was done in searchlight matters until the outbreak of the Spanish War when, with a part of the large amount of emergency funds at once made available by Congress, some forty-odd searchlights were purchased. The greater portion of these were 30-inch lights, there being a few 24-inch and a few 36-inch; the latter, the largest size obtainable in this country. The searchlight mechanisms and everything connected with them, except the mirrors, were of American manufacture. The mirrors, however, could not be obtained in this country and had to be purchased abroad.

Up until the transfer, in the spring of 1901, of submarine mining from the Engineers to the Coast Artillery, searchlight matters seemed to have been handled largely as an accessory to submarine mines. The original use of the searchlight at Willetts Point had been for tracking a vessel proceeding through a supposedly mined field, and in the report of the Endicott Board the use of searchlights seems to have been considered as a necessary adjunct to submarine mines. In the annual estimates submitted by the War Department to Congress, the cost of purchasing searchlights was included in the estimates for submarine mine material and was so included in the annual reports of the Chief of Engineers.

However, in 1901, probably as one of the indirect results of the transfer of the submarine mining system to the Coast Artillery, the subject of searchlights was taken up anew and separately, and the 1901 fortification appropriation act contained an item of $15,000 for the purchase and installation of searchlights and the electric plants pertaining to them. Since then the two subjects have been kept separate.

In this same year, 1901, the Board of Engineers made a careful study of the number of searchlights needed in our seacoast defenses and recommended the installation of 344 lights, including 24-inch lights, 30-inch lights, and 36-inch lights; the latter being the largest then available.

In the next year, 1902, the Board of Engineers submitted another long report. In it they stated that the 60-inch light, which had just appeared, was a most satisfactory large light, having a probable range under ordinary atmospheric conditions of from 6,000 to 8,000 yards, as against 4,000 to 6,000 yards for the 36-inch light. They further recommended that searchlights should be placed as near the shore as possible so as to take full advantage of their comparatively short range, but that their positions should be thoroughly concealed during the day time. They recommended that as far as the uses of the lights were concerned, they be divided into two classes, searching lights and illuminating lights; the former to be the more powerful, located well in advance, and so disposed as to cover all avenues of approach; and the latter to be more retired, preferably to positions in the flanks of the batteries to which they pertained, and to be used for illuminating vessels whose presence had been detected by the searching lights. The board further drew attention to the fact that the crossing of searchlight beams should be avoided if possible, as it is very difficult to see, through one searchlight beam, a target illuminated by another.

The above-mentioned reports of the Board of Engineers on the subject of searchlights were published in Engineer Mimeograph 39 and its supplements. An additional supplement was published in the fall of 1904 containing a report by Maj. S. W. Roessler, the district Engineer officer at Portland, Me., upon the use of the searchlights in the maneuvers of that year in that vicinity.

In 1904 it was decided that during the year 1905 the Army and Navy would cooperate in joint maneuvers in Chesapeake Bay and its tributaries. In preparation for these maneuvers, arrangements were made to mount at least 10 searchlights in the defenses of Hampton Roads and to provide power for these lights. A detailed report on this subject was published in Mimeograph No. 91 in which there are related in some detail the difficulties that were encountered and defects that were developed during the preparations for these maneuvers, the steps that were taken to correct the defects, and the improvements that should be made in future.

By the time of the organization of the Taft Board in 1905, the importance of searchlights for nocturnal battlefield illumination had been fully realized. The Taft Board therefore gave careful consideration to the subject and on page 19 they state as follows:

> The various combined Army and Navy maneuvers and exercises have clearly demonstrated their importance for disclosing the presence of an enemy at night. When properly located, the lights illuminate the ships so that the system of range finding, fire control and direction becomes as efficient at night as during the day for accurately fixing the position of the ships, and does away with the advantages the darkness would give the attack in attempted "run by" or in forcing a passage.
>
> Because of the effect of beams of light on each other and on auxiliaries of defense, experiments have demonstrated that the proper number and locations of searchlights in each harbor are matters that can be determined only after repeated local trials, and as a consequence the preparation of an estimate of the cost of perfected searchlight apparatus for all of the defended harbors, which is more than a fair approximation, is impracticable. The estimate submitted is based on a study of the fortified harbors, with no provision for any reserve.

Later on, on page 39 of their report, they state as follows:

> Searchlights, originally intended for protecting the mine fields against countermining operations at night, have become an indispensable adjunct to an efficient gun defense. Experiments made with searchlights during various combined Army and Navy maneuvers and exercises show the necessity for—
>
> 1. Searching lights for illuminating and searching all waters of approach.
> 2. Illuminating lights for lighting up the hostile ship during its advance after discovery by the searching light, in order that its exact location with respect to the guns may be constantly determined by the system of range finding, fire control and direction.
>
> The most powerful lights are required for "searching," and the illuminating light must give a beam of sufficient intensity to light up the target for the effective ranges of the guns. The 24-inch and 30-inch projectors have shown lack of power to do the work required, and at present the 36-inch and the 60-inch lights are the adopted types.
>
> The location of the lights in any particular harbor is a matter of the greatest importance, as serious disadvantages may otherwise result to the defense, due to the effect of interfering beams of light on each other and on other auxiliaries of defense. It has been clearly demonstrated that proper locations can be determined only after systematic and intelligent local experiments made by the troops using powerful searchlights, moved and grouped at will. Upon the locations from which all the avenues of approach can be properly illuminated depends the number of lights required in each case. Such experimentation has as yet been very limited, and, therefore, accurate estimates can not be prepared. The one submitted is based on an assignment of two searching lights to the battle commander, and an illuminating light to each fire commander without any reserve. Whether a greater number of lights will be required can only be determined after careful and extensive experiments.

In the report of the Taft Board it is stated that, with the proper use of searchlights, fire control and fire direction will become as efficient by night as by day. Subsequent events, however, would appear to indicate that in making this statement the board was unduly optimistic.

From the quotations made above from the report of the Taft Board, it will be noticed that the recommendation is made for the use of the 36-inch and the 60-inch searchlights only; the 36-inch for illuminating mine fields and the targets of rapid-fire guns, but the 60-inch searchlight to be used, to the exclusion of the smaller sizes, for distant searching or illumination. However, very shortly after the acceptance of the Taft Board report, there was a tendency to push the location of the mine fields much farther to the front and beyond the effective range of 36-inch searchlight. Consequently, only a few years after the submission of the Taft Board report, it was found that the 36-inch searchlight was not powerful enough, thus leaving the 60-inch light as the only size suitable for sea-coast use.

Among the other recommendations of the Taft Board was one to the effect that the number of searchlights needed in any harbor and their proper location should be determined only by trial. This recommendation was adopted by the War Department and there were therefore, gathered together a number of portable 36-inch searchlight outfits. These were tentatively combined into a so-called "Searchlight brigade" and were placed in charge of Capt. (now Brig. Gen.) W. C. Davis of the Coast Artillery Corps. The searchlight brigade was first mobilized in Portland Harbor, Me. The searchlights were located at certain places and were then moved around from place to place until it was considered that the question of the number of lights necessary and of their proper location had been satisfactorily determined. The searchlight brigade was then moved to another harbor, and so on, until all the principal harbors on our coast had been visited.

From the acceptance of the Taft Board report until the entrance of the United States into the recent World War, regular but small appropriations available for searchlight purchase and installation were made annually, and with the funds thus made available, considerable progress was made in the purchase and installation of the searchlights called for by the various harbor defense projects and in the substitution of 60-inch lights for the smaller ones.

Usually, at least in later years, there have been available in addition, small allotments from the appropriations for Engineer equipment which have been used in the development and purchase of portable searchlights for use with a field army. These allotments, however, and the appropriations for coast defense searchlights have been too small to permit of much experimental or development work. For that reason, improvements in searchlights have been made much more slowly than was desirable.

But in spite of the scarcity of funds, considerable had been accomplished; the most important progress made being in the development of two satisfactory types of high intensity lights, as will hereafter be mentioned, and in the development of the manufacture in this country of satisfactory searchlight mirrors.

As soon as the United States entered into the World War, greatly increased appropriations became available for searchlight work, and with the funds thus made available and due to the impetus given by the war, many developments have been made, especially in the way of increasing the portability of the searchlights and of their generating sets.

MECHANISM AND PARTS OF THE SEARCHLIGHT.

In its older form, and in the form still standard for seacoast work, a projector consists essentially of a cylindrical metal drum having a diameter slightly greater than that of the mirror. When in operation, the axis of this drum is horizontal and points toward the object to be illuminated. At the rear end of the cylinder is the mirror set in its frame and, at the front end, the so-called "front door," composed normally of plate-glass strips. The carbons, between the ends of which the arc is formed, are held in position with their ends in or near the focus of the mirror by means of two clamps on the arms of the lamp mechanism, which is located in a box attached to the bottom of the drum.

Opposite each other on the sides of the drum, and in such a position that the line joining them is horizontal and passes through the center of gravity of the drum and contents, there are attached the trunnions. About the horizontal axis formed by these trunnions, the drum can be revolved so that its axis and, therefore, the beam of light will move in a vertical plane. The trunnions rest in the sockets at the top of two arms, the lower ends of which are fastened to the upper plate of the searchlight base. This upper plate of the searchlight base can be revolved about a vertical axis and in this way the axis of the drum, and therefore the beam of the searchlight is moved in azimuth.

Lamps.

The only source of light which up to the present time has been found sufficiently powerful for distant illumination in connection with seacoast defense is the electric carbon arc—that is, the arc that is formed by two pieces of carbon which are placed in contact and are then suddenly separated while a strong electric current is passing from one to the other. When this happens, not only does the electric arc between the two pieces of carbon give off a great deal of light, but the ends of the two pieces of carbon become heated to incandescence and give off even a greater quantity. It is found that due to the passage of the electric current through the arc, the ends of the two pieces of carbon are slowly consumed and that this wearing away takes place differently in the two carbons. The negative carbon is worn away almost to a point, while the end of the positive carbon is cut out into the form of a crater. The surface of this crater is apparently the hottest place connected with the arc and gives off the greatest amount of light.

It has been found that the most satisfactory arc is formed when the positive carbon is considerably larger than the negative one. Since the negative carbon is the smaller and is worn into a point, and since the larger portion of the light comes from the crater of the positive carbon, it is customary in searchlights to place the positive carbon in the axis of the mirror, exactly at the focus, and with the crater pointing toward the mirror. The negative carbon is placed between the positive carbon and the mirror in such a way as to cut off as little light as possible. Usually this negative carbon is in direct prolongation of the positive one. Sometimes, however, it is set at a slight angle.

In order that the arc may burn properly several things are essential. First, the carbons must be placed in contact and an electric current must be passed through them before an attempt is made to strike the arc; next, the carbons must be drawn quickly a short distance apart, thus striking the arc; and third, after the arc is struck, the carbons must be kept exactly the proper distance apart, because it is found that slight variations in the length of the arc make considerable differences in the amount of light that is given off. Furthermore, as the carbons are consumed they must be fed together so as to make up for the consumption, and this must be done in such a manner as to keep the center of the crater of the positive carbon exactly in the focus of the mirror. Since the two carbons are consumed at different rates, this is not a simple matter.

The method by which the arc is struck, its length regulated, and the carbons fed up is called the "regulation of the light." The mechanism for doing all this must operate practically automatically. It is located, in the old form of searchlight, in the box just outside of the lower part of the drum, the arms holding the carbon passing up from the lamp box through slots in the shell of the drum to the clamps holding the carbons in their proper position.

It is not proposed to go into any further details regarding this mechanism, because it is not easy to understand without numerous drawings and preferably a lamp itself to examine.

Rheostat.

The automatic regulation of the length of the arc is made simpler by the fact that the carbon arc has a high electric resistance. Consequently, slight changes in the length of the arc make considerable variations in the amount of the electric resistance in the circuit and, therefore, in the strength of the current which is flowing. By placing the coil of an electromagnet in series with the arc, the strength of this magnet will vary with the varying lengths of arc, and the magnet can be so placed that its tendency will be to move the carbons, or one of them, in such a direction as to tend to counteract the changes in the length of the arc as fast as they occur.

With an extremely short arc, the drop across the arc is about 55 volts, and this drop increases with the length of the arc up to 70 or 75 volts. It might appear, therefore, that a voltage of about 80 is all that is necessary at the terminals of the searchlights. Experience, however, has shown that in order that a searchlight may burn steadily, it is essential that there be a considerable resistance in the circuit in addition to that of the arc. It is therefore necessary to put a rheostat in series. This is usually mounted close to the lamp, and in addition to merely steadying the current, the rheostat can be used so as to be of great assistance in the regulation of the arc.

Where a searchlight is mounted very close to a source of power furnishing the ordinary voltage of 110 volts, the rheostat must be heavy enough to consume all of the voltage not necessary for the operation of the lamp. However, in order to give additional protection to the power plant, and incidentally to reduce the noise from the generator, it is customary to place the power plant a considerable distance from the searchlight and to make the connection by a length of cable. The electric resistance of this cable acts in the same way as the resistance of the rheostat and makes it unnecessary to have a very large rheostat in the vicinity of the lamp.

Carbons.

The ordinary electric arc light had for several years been in use for street and factory illumination before the attempt was made to utilize it in the modern form of searchlight. Of course, a satisfactory type of carbon for the older arc lights had been developed, but when the attempt was made to use more powerful arcs in the searchlights these older forms of carbon were found unsatisfactory, and it was seen to be necessary to develop different sizes and different types of carbon for the different sizes and types of searchlights. The greater the intensity of the current to be used, the larger it was found the carbons must be, the standard carbons required by the 60-inch light having a diameter of 2 inches for the positive and 1 inch for the negative. The most satisfactory arc was formed between these carbons with a current intensity of from 180 to 200 amperes.

It was only after considerable difficulty and much experimentation that carbons of the proper quality were obtained, and even in a single lot of carbons some would seem to burn well and some not. It was noticed that when a brand new box of carbons was received from the factory and opened, the first carbons usually burned very well and the others might or might not burn satisfactorily. For a long time the cause of this irregularity was puzzling, but it was finally discovered that it was due to the carbons having a tendency to absorb the moisture from the atmosphere and that they burned well only when perfectly dry. The first carbon taken out of the can, which had been hermetically sealed, was dry and burned well. If the can were immediately sealed up, the others would burn well also, but if they were allowed to lie around in the air, they would absorb moisture and burn badly, at least for a considerable time after being put in the lamp.

It was, therefore, found to be necessary before using the carbons in the lamp to heat and dry them. When the lamp was in operation, the carbons to be next used could easily be placed in or near the drum and in this way would be heated up before they were needed. This was all right after the light was in operation but of course with the first carbon the arc would flicker. It was soon found that the way to avoid this was to put the carbons in the lamp considerably before it was put in operation and then to pass through them a current sufficiently strong to slightly heat them up but not strong enough to strike the arc.

High Intensity Lights.

Even with the best type of carbon the old simple carbon arc searchlights were deficient in illuminating power and attempts were naturally made to increase this.

The most natural way that suggested itself was to increase the intensity of the current. By using the same size carbon and increasing the current density per unit of surface of the crater of the positive carbon, the temperature of the surface of the crater would be increased and this would increase the amount of light given off. When this was tried, it was found that the edges were apt to flake off, leaving the crater irregular in shape and actually decreasing instead of increasing the amount of light given off.

After careful deliberation, it was finally decided that in all probability this breaking off of the edges of the crater was due to the high temperature of these edges, and the next attempt was to keep the edges of the crater cool by blowing along the surface of the positive carbon a blast of cool vapor or air.

The first successful attempt to do this seems to have been with vapor of alcohol. This vapor, of course, would catch fire as it approached the arc but the temperature of combustion was much less than that of the edges of the crater, and so these edges were kept comparatively cool and did not break off as they did without the blast. This is the principle of the so-called "Beck" light.

Later, another and more successful light was developed in which the blast consists of plain air. This is the method adopted in the so-called "Sperry" light.

After considerable experimentation, it was found that it was possible by the use of these blasts of cool air or vapor to keep the edges of the crater cool and thus prevent them from cracking off, while at the same time greatly raising the temperature of the surface of the interior of the crater by a great increase in the current density.

This increase in the current density could be secured in two ways, either by keeping the same size carbon and increasing the strength of the electric current, or by keeping the same strength of current and decreasing the size of the carbon. To avoid the necessity of changing the generating plants fitted for use with searchlights, the second of these plans for increasing the current density was followed. The size of the carbon was decreased while still maintaining the standard current of from 180 to 200 amperes.

Of course, this required something of a change in the quality of the carbons used, but there has now been developed as the standard positive carbon for use with the 60-inch searchlights, one which is copper-plated on the outside, having a small but specially prepared core and being but about five-eighths of an inch in diameter. The diameter of the negative carbon is approximately half of this size. Since the new positive carbon is about five-eighths of an inch in diameter, or slightly less than one-third of the size of the 2-inch carbon which was standard in the old searchlights, it is evident that the current density is approximately ten times greater. This great increase in the current density has resulted in a correspondingly great increase in the temperature of the surface of the crater, and in the emission of a very much greater quantity of light. Furthermore, the reduction in the size of the surface from which the light is given off has resulted, as will be shown hereafter, in a much greater concentration of the beam.

The steadiness of the arc and the regularity of consumption of the different sides of the crater have further been much improved by an attachment which slowly rotates the carbons about their axes as they are consumed.

Experiments are now under way with a view to the development of still more powerful lights which will make use of currents approximating five hundred amperes. This, of course, will require larger carbons, it being probable that the positive carbon will be approximately 1 inch in diameter.

The new high-intensity mechanism was naturally applied first to the old form of searchlight with the drum and the front door. In fact, although a few brand new lights were purchased, the first general use of the high-intensity principle was made by modifying the old searchlights, keeping the drums and front doors practically as they were and inserting the new lamp mechanism in place of the old. This was the status at the entrance of the United States into the World War.

Shortly thereafter ample funds for searchlight development became available, and among the tests and measurements made were some to determine the extent to which the glass front door was an absorbent of light. That it absorbed some light was known, but that it absorbed much was not believed to be true, and it was a considerable surprise, therefore, when it was found that this front door absorbed nearly one-fourth of the light reflected from the mirror and reduced the efficiency of the beam to that extent.

The object of the front door of the old lamp was to prevent the flickering of the arc, due to the irregular air currents which might have entered through an open front. The use of the strong, concentrated air-blast of the high intensity mechanism did away with any possibility of interference by these light irregular air currents, and consequently, after the high intensity mechanism was introduced, the front door was no longer a necessity.

The two most essential parts of the searchlight left after the abandonment of the use of the front door were the lamp mechanism and the mirror. The only function now performed by the drum was to hold the mirror and the lamp mechanism in their proper relative positions and it would appear that there might be a simpler and lighter construction for doing this.

An attempt was therefore made to do away with the drum, mounting the mirror merely in a frame, on the bottom side of which was attached the lamp mechanism. In the meantime, however, the type of lamp mechanism which had been found to work extremely well when the searchlight was used either horizontally or at moderate angles of elevation only, failed when the beam was directed nearly to the zenith as was frequently necessary in antiaircraft work. A new mechanism had to be devised which would satisfy this requirement.

In this way there was slowly developed what is called the "dish-pan" type of searchlight. This consists essentially of a mirror and its frame, the lamp mechanism being contained in a comparatively small cylinder which is inserted from the rear through a hole cut through the center of the mirror.

Doing away with the drum, the front door, and other portions of the mechanism resulted in a great decrease of weight. This made it possible to use lighter arms for supporting the mirror and lamp, and this, in turn, permitted the use of a lighter base. By omitting from the base the distant control mechanism (which was found to be unnecessary in antiaircraft lights) the weight of the new 60-inch dish-pan light, even including the weight of the small rubber-wheeled car for moving it around, was reduced to approximately 650 pounds, as against the 6,000 or 7,000 pounds of the old standard 60-inch seacoast light.

The various improvements which have been described, the high-intensity arcs and the abandonment of the front doors, have greatly increased the illuminating range of the searchlights. In a test a few years ago at Fort Monroe with the high-intensity lights, it was found that both the "Beck" and "Sperry" lights would, under ordinary atmospheric conditions, give sufficient illumination at 13,000 yards. In these tests the front doors were used and the lights tested did not have all the latest improvements. With the addition of these improvements and with the abandonment of the front door, it is believed that the normal illuminating range of the best 60-inch searchlight may be placed at approximately 15,000 yards.

Mirror.

Theoretically, the best form of mirror is parabolic. If the mirrors were truly parabolic and if all the light issued from a point truly at the focus of the mirror, all the rays which strike the mirror would, after reflection, be parallel. In fact, however, the light actually does not issue from a geometrical point but from practically the entire surface of the crater of the positive carbon. Consequently, with a single exception, none of these luminous points can be exactly at the focus of the mirror. Rays of light issuing from a luminous point slightly to the side of the focus of a parabolic mirror are, after reflection, nearly parallel to one another, but they are not parallel to the beam of light made up of the reflected rays which issue from a point exactly in the focus. Consequently, even with a truly parabolic reflector, the rays of light tend to diverge somewhat and this divergence is greater the greater the luminous area from which the rays come. The smaller the size of the luminous crater, therefore, the less will be the divergence of the rays. This is one of the reasons why the beams of the modern high intensity lights are less divergent than those of the old standard lights, the diameter of the positive carbon of these new high intensity 60-inch lights being about five-eighths of an inch, or about one-third of the diameter of the positive carbon of the older standard lights.

The object of the searchlight being to illuminate a distant object as brightly as possible, it is necessary, in order to get the maximum amount of illumination of this distant object, that the beam of any searchlight should be as little divergent as possible. Consequently, the light, to be efficient, must always be kept properly focused. If the luminous point be too close to the mirror the rays on leaving have a tendency to diverge. If the luminous point be too far away from the mirror, the rays have a tendency to converge at a point some distance to the front, and after crossing that point to diverge again. The net result, therefore, when the light is out of focus in either direction, is the divergence of the beam and this decreases the intensity of the distant illumination.

The subject has been sometimes discussed as to whether searchlight mirrors should be short focused or long focused. Of course, with a mirror of the same diameter, the nearer it is to the light the larger the spherical angle centering at the light that will be intercepted by the mirror, and the larger the percentage of rays coming from any point that will be reflected from the mirror. However, the closer the mirror is to the light, the greater will be the divergence of the axes of the beams of rays from different points of the crater. So in illumination at a great distance, what is gained in one way may be lost in another. Furthermore, the closer the mirror is to the arc, the greater the tendency to heat up, damage, crack, or distort the mirror. In fact, it would appear that the best focal length for a searchlight mirror is a question that can be determined by experimentation only, and the present adopted standard seems to be about as satisfactory as any.

The mirrors which, up to the present time, have been found most satisfactory for searchlight work are of silvered glass, although many experiments have been made with metal mirrors.

Up to some eight or ten years ago it was not possible to obtain satisfactory glass searchlight mirrors manufactured in this country and all of the mirrors used had to be obtained from abroad. The few attempts that had been made in this country to manufacture glass mirrors had failed, and the annual appropriations available for the purchase of searchlight mirrors were so small that it hardly seemed to the glass manufacturers that it was worth while to go to the expense of installing special machinery to make such mirrors. However, about 1910, with an increase in the size of the annual appropriations, the Engineer officers engaged in the purchase of searchlight mirrors succeeded in getting an American manufacturer interested in the subject and a few years later very successful 60-inch mirrors were turned out. Since that time, all glass mirrors purchased have been of domestic manufacture and, under the impetus of the enormous expenditures of the recent war, other manufacturers were induced to go into the business and have succeeded in making satisfactory mirrors. Consequently this country is no longer dependent upon foreign manufacture.

A glass mirror, however, requires careful handling; in fact, several have been broken while being screwed into their frames. Others, on account of not being properly annealed, have been cracked by the heat of the arc, especially when exposed to a sudden blast of cool air. Furthermore, experiments have indicated that a glass mirror when struck by a bullet is apt to be badly shattered, whereas a properly made mirror may be punctured many times by small-arms bullets without being broken or even having its reflecting power seriously diminished.

In order, therefore, to obtain if possible a mirror which will be less vulnerable, experiments have been made for very many years, both in this country and abroad, looking to the development of metal mirrors.

It was first attempted to build a mirror having a silver surface. It was soon found, however, that in the high temperature to which the surface is exposed silver soon tarnishes and loses much of its reflecting power. Attempts were then made to find some form of lacquer or varnish which could be applied to the silver surface and which, while not seriously diminishing the reflecting power, would nevertheless prevent it from tarnishing. Experiments, however, showed that although it was comparatively easy to find a lacquer which would prevent the silver itself from tarnishing, the lacquer showed a tendency, when exposed to the high temperature, to become opaque.

Other experiments were made with mirrors having a nickel surface and with mirrors composed of various alloys of which one, the so-called "Monel" metal, appeared at first to give the greatest promise.

Gold-plated mirrors were also tried, and as early as 1905, the Sautter-Harlé Co., of France, were able to manufacture a successful gold-plated mirror. A number of these were purchased for use in this country and were first thought to be fairly satisfactory. This gold-plated mirror, however, gives a beam of a somewhat yellow color, quite different from the bright blue color of the beam from a glass or silver mirror. It was expected by some that this yellow beam would show in the air greater penetrative power than the silver beam, and therefore would be comparatively more efficient at a distance. This promise appears not to have been fulfilled and, after considerable experimentation, it has been finally decided that the gold-plated mirror is not as efficient as the silver and glass mirrors.

As has been stated, the experimental development of the details of searchlight mechanism, and especially of the metal mirror, was largely retarded in this country by a deficiency in the funds available for experimentation, but this condition of scarcity of funds was changed during the World War. With the increased funds, rapid experimentation became possible and the manufacture of metal mirrors was again attempted and on a larger scale than ever before.

Instead of continuing to mold a metal disk into its approximately correct shape and then grind and polish it, a new method of manufacture was tried which is as follows: There is first manufactured a convex glass mirror exactly parabolic in shape and having exactly the curvature desired for the metal mirror, but reversed. The surface of the glass mirror is then covered with a uniformly thin coating of a certain kind of cement. On the outside of this cement layer there is deposited by electrolytic means, a layer of silver and, behind it a thicker layer of copper to stiffen the silver. The metal is then strengthened by a thick cement backing. When this has hardened, the layer of cement between the glass and the layer of silver is dissolved, and the metal mirror is left in its proper shape and ready for polishing.

The early mirrors made by this new process were, as was to be expected, not a complete success, but it is thought by the officers in charge of this development that the results have been very promising and that before long the successful manufacture of metal mirrors will be accomplished.

Front Door.

The object of the front door is to prevent the flickering of the arc, and thus to steady the light. In the earlier searchlights, before the front door was used, it was noted that the arc seemed to flicker badly and that this tendency increased in a wind. After considerable discussion, it was decided that this flickering must be due largely to the currents of air entering through the open front of the drum and a front door of plate glass was, therefore, introduced to close this opening. That the absence of this front door was the sole cause of this flickering was not thought for a moment, but that it was a contributory cause was evident for the use of the front door made the light much steadier. The front door therefore became an essential part of the searchlight, at least as long as the simple carbon arc was used. More recently, as has been noted, the introduction of the high intensity mechanism has rendered the front door no longer necessary.

The door was hinged to the drum on one side and was provided with a fastening on the other so it could be clamped shut. When opened, it provided a convenient means of getting at and adjusting the mechanism in the drum.

The door consists normally of plate-glass strips set in a suitable frame, the strips being cut from plane glass so as to cause no change in direction of the rays of light as they pass through. Strips are used instead of a solid piece of glass because they are more easily obtainable and if one be broken only that one has to be replaced.

In the early days of the use of searchlights, it was thought by some that it might increase the usefulness of the light for searching purposes if the beam could be made slightly divergent in a horizontal direction while still being kept as convergent as possible in the vertical plane. It was proposed to do this by making the front door of the drum of the searchlight, not of plane glass but of prismatic vertical strips, the angle of divergence of the prisms increasing from the center of the door to the sides. It was thought that by this arrangement the beam would cover a larger horizontal field which would make it possible in searching to move it somewhat more rapidly in azimuth.

Where the objects which are being searched for are at very moderate distances from the light such a divergent ray might possibly be of use, but as a rule, on the seacoast, the objects which are being sought are at or near the maximum range of the light; in other words, so far away that even with the greatest possible convergence of beam the illumination is barely sufficient. After a small amount of experimentation, therefore, this idea of prismatic strips for the front door was abandoned.

Signaling Apparatus.

Long before the invention of the modern searchlight, night signaling by means of the flash-light lantern had been in common Army use. The introduction of this much more powerful source of light naturally suggested that the searchlight also might be used for signaling purposes, all that was necessary being some form of movable shutter that could be placed in the beam.

The first form of shutter consisted of a set of small parallel slats fastened in a frame which was attached to the drum in front of the front door. These slats were all connected to and operated by a lever. When open, the slats were in the plane of the beam, and therefore obstructed little light. When closed, they hid the light completely and, by a proper manipulation of the operating lever, dots and dashes could be sent as desired.

With flash-light signaling by a lantern, it is usually necessary that the light be directed toward the person who is being signaled to, but with searchlights this was soon found to be unnecessary as a beam directed at a considerable angle of elevation and in the general direction of the person with whom it is desired to communicate, can be plainly seen and the message can be read from a distance of many miles.

The form of shutter just mentioned consisted of metal slats and was exceedingly heavy. It threw the drum out of balance to such an extent that special trunnions had to be attached for use with the shutter. Furthermore, even though the slats were turned in the plane of the beam some light was intercepted. Consequently, another form of shutter was tried which worked on the iris principle, like the shutters used in photographic cameras. This form has been found to be quite satisfactory, but it is somewhat slower in operation than the other.

Still another apparatus was tried consisting of a small disk that could be raised up between the arc and the mirror, thus temporarily killing the beam though not completely occulting the light.

Occulter.

The slat shutter and the iris shutter just referred to have at times been put to other uses than signaling. It frequently happens that a searchlight has to be put suddenly into operation, and it was the experience with the old simple carbon arcs that for some time after the arc was struck it flickered badly and the illumination from it was not satisfactory. It was therefore proposed to keep the light always in operation, or at least to light it with the shutter closed whenever it was thought the light might be needed before long. Then when the light was needed suddenly, all it was necessary to do was to open the shutter. It was found, however, that not only is this expensive in the consumption of the carbons, but that the energy generated by the arc when shut in by the shutter and unable to escape, produces such high temperatures as to cause considerable damage.

Another method of obtaining a satisfactory arc when the light is put into operation suddenly is, before the light is needed, to pass through the carbons when in contact, a current not sufficient to cause an arc to be struck or to heat the carbons to incandescence. The theory upon which this is based is that the flickering of the carbon when the light is first put in operation is largely due to the sudden and local increase of temperature when the arc is suddenly formed at the ends of cold carbons. The smaller current passing through the carbons heats them up considerably and, consequently, when the arc is struck there are not as great differences in temperature as with cold carbons and the flickering is noticeably smaller.

Fortunately, however, most of the difficulty in the flickering of a newly struck arc has been done away with by the introduction of the new high intensity light which can be put in operation very quickly and which comes into operation with practically its full intensity and without much flickering.

Control Mechanism.

The movements of a searchlight, by means of which the beam is thrown in any desired direction, is called "searchlight control." In order that the beam may be directed in any direction which may be desired, it is evident that two motions are necessary, one in azimuth and one in elevation. The one in elevation is obtained by rotating the searchlight drum (or the mirror frame in the high intensity searchlight) about the horizontal axis made by the trunnions which support the drum or frame. The movement of the beam in azimuth is obtained by revolving the upper part of the base about a vertical axis.

In the original searchlights these motions in azimuth and elevation were given by hand, the operator, of course, standing close to the light. It was found, however, that persons as close to the light as the hand operators can see but little of the objects illuminated by the beam and are, in fact, unable to keep the beam upon a distant dim object that is in motion. For this purpose the person controlling the movement of the light must be at a considerable distance from it.

The attempt was first made to have the hand operators directed by telephone as to how the light must be moved but this proved so unsatisfactory that steps were then taken to develop, if possible, a mechanism by means of which the actual movements of the drum would be electrically controlled from a distance.

Several very satisfactory forms were developed at an early date, and by 1905 the General Electric Co. had developed a distant control mechanism which could be worked successfully from distances as great as 4,000 feet, and under favorable conditions from distances of nearly 10,000 feet. The controller used was very simple in form and permitted of two speeds in elevation and four speeds in azimuth. To move the beam slowly to the right, the controller handle was moved to the right to the first notch and as long as it was held there the beam would continue to move in azimuth to the right and at the same speed. To increase the speed the handle was moved to another notch, etc. To elevate the beam the controller handle was raised, and to depress it the handle was lowered. As long as the handle was held in one notch the control mechanism of the light would work at a steady speed. When the handle was brought back to the normal position, the beam would stop wherever it happened to be.

Up to 1905 no attempt seems to have been made to direct searchlight beams by means of azimuth readings. In telephoning to the detachment at a searchlight as to the use of the hand control, or to the man at the controller as to electric control, directions were stated in general terms only or were referred to local objects.

It soon appeared, however, that this was rather a rough and indefinite method of indicating directions and that greater definiteness would be insured by using azimuth readings. Accordingly, azimuth readings were painted around the bases of all searchlights installed in fixed positions and were so oriented that the reading of the azimuth scale indicated the azimuth of the beam. For hand operation this was all that was needed but the adopted form of distant controller gave no indication to the man at the controller as to the azimuth of the beam, if in operation, or as to the direction in which the light was pointed, if not in operation. To successfully control searchlights by means of azimuth readings, some such indication appeared to be necessary.

In order to accomplish this, there was developed a new form of controller known as the "step-by-step" controller. In the old General Electric form, as long as the controller handle was held to the right, the controlling mechanism would keep the beam moving in azimuth to the right. When the controller handle was put back to the normal position the motion of the searchlight would be stopped. Similarly with motions in elevation. With this new step-by-step controller it was necessary, in order to keep the light moving in azimuth, to keep the controller handle rotating and the velocity of motion in azimuth was regulated by the speed of rotating the handle. As soon as the handle stopped, the motion of the beam would stop too. Incidentally, as the handle was rotated figures showing the azimuth of the beam would appear in the controller.

This form of controller has not, however, proved to be thoroughly satisfactory. It does not permit a sufficiently rapid change of direction where the target has to be changed and, moreover, the motion of the beam is not perfectly steady but by jumps. As an apparatus for moving the beam, it is far inferior to the older form and has the sole advantage of azimuth indication. Work is therefore in progress now on the development of a new form of controller which it is hoped will unite the advantages of both of the older forms and will have the disadvantages of neither.

Cables.

Ordinarily, in order to give protection to the power plant which it is not necessary to expose, the power plant and searchlight are separated by a considerable distance and this makes it necessary to have a connection by an electric wire or cable. The cables used are rubber-covered twin conductors. The size of copper has to be, of course, sufficient to carry, without undue heating, the full amperage necessary for the operation of the light, but as the voltage necessary at the searchlight is considerably less than the 110 volts standard at the generator, a loss of 20 volts or so in the passage of the current through the cable is not a disadvantage. It is to a certain extent an advantage as the resistance of the cable under these conditions forms part of the steadying resistance which seems to be necessary for the perfect operation of the lamp.

However, it should be noted that in the control mechanism there are a number of motors, and these motors have been found to operate best when provided with the voltage for which they were wound. Where the voltage at the terminals of the searchlight varies rapidly, or where it is much below the standard for which the control motors were designed, the control mechanism has been found not to work very well. At least that was the case with General Electric control that was standard in 1905. To overcome this difficulty, it became customary to obtain the power for operating the control mechanism, not from the searchlight terminals, but from the source of power, by connecting the terminals of the control mechanism all the way back to the terminals at the source of power. This was done by making the searchlight power cable four-cored, two of the cores being large for carrying the light current, and the other two much smaller for furnishing power to the control mechanism. This was and still is the standard form of cable for all searchlights furnished with distant control mechanism. Where there is no distant control mechanism a two-cored cable is sufficient.

The controller cable is usually 10-cored, although the number of cores depends upon the type of controller used. The operation of the control mechanism in the base of the lamp makes use of relays, and consequently the wires of the controller cable can be quite small.

This cable is ordinarily furnished in lengths of 1,000 feet and at the ends of these cables are couplings for connecting the various lengths together and for connecting one end of the controller cable to the controller and the other to the control mechanism at the lamp. Of course, it is essential, when making these joints, that the connections be made between the proper wires, and this requires that the couplings should be of a special form to fit together in one way, and one way only.

When possible, both the power and the controller cables are laid in ducts, sometimes they are merely trenched, and in a few cases they are strung in the air or on the ground. The latter is frequently necessary with portable searchlights. In connection with the installation in ducts, it should be noted that some of the forms of couplings used for controller cables are so large they can not be pulled through ducts. In this case the couplings are removed, the cable is pulled in and the couplings are then replaced on the ends.

Power Plants for Searchlights.

This subject was discussed in the chapter on electrical installations and need not be repeated here.

CLASSIFICATION OF SEARCHLIGHTS.

A classification of searchlights according to their size is a necessary and useful one. In addition to this method, the attempt was once made to classify them according to the principal use for which each light was intended, as follows:

First. What may be called a "sentinel beam," that is, it was supposed that it might be desirable in some localities to throw a searchlight beam across a channel and keep it fixed in that position so that any vessel approaching would have to pass through this beam.

Second. There was to be a class of so-called "searching lights" which were to be swung back and forth over a specified area to discover the presence of the enemy.

Third. There was to be a class of so-called "illuminating lights" for lighting up a target after its presence had been discovered by a searching light. In other words, when a searching light had picked up a target and observation showed it to be an enemy, an illuminating light would be turned upon the target, thus freeing the searching light so that it might resume the search for other vessels. The illuminating light would then be kept upon the vessel as it proceeded on its course so that it might be observed by the range-finding stations and, if necessary, by the observers at the sighting telescopes of the guns.

Fourth. There was to be a class of so-called "blinding" lights, that is, lights which upon the approach of any enemy's vessel were to be concentrated upon the pilot house or bridge with the intention of so blinding and confusing the navigators as to interfere with the navigation of the vessels.

In addition to the classifications mentioned above, there was to be another classification depending upon the person who was to have charge of the operation of the light. Thus it was supposed that certain lights would be kept exclusively under the control of the battle commander and be known as "battle commander's lights." There would be other lights under the control of the fire commanders and called "fire commander's lights." Then the mine commander would have other lights for illuminating the mine field, and possibly in some cases there might be even "battery commander's lights."

Of course, it was supposed to be possible that any one particular searchlight might at different times and under different conditions fulfill several or possibly all of the different functions, but each particular function was supposed to be separate and independent of the others and carried out under different regulations.

For many years these distinctions were insisted upon, but it was developed by experience that they were unnecessary, and all or most of them have gradually fallen into disuse.

Thus it was found necessary to do away with the class of so-called sentinel beams because, if a beam remains in a fixed position, an enemy's vessel can approach quite close to it and keep just outside of the beam. Its presence not being known, it can bring a sudden fire upon the light and destroy it. It was therefore decided that it was necessary to keep all lights moving to a greater or less extent, so that the operation of a so-called sentinel light became essentially the same as that of a searching light.

It was also found necessary to do away with the so-called blinding lights, for the reasons that, except at exceedingly short ranges, they did not blind and all that it is necessary for the navigators of the vessel upon whom the light is thrown to do is to use dark glasses and to proceed on their way. In fact, in the case where the location of the blinding light was known to the enemy, its use really was an aid to navigation. It is needless to say that if a powerful light at a comparatively short range be thrown into the eyes of the navigator of a vessel it makes him, for the time being, unable to distinguish small objects such as small boats, buoys, etc., and it may to some extent interfere with navigation. But it is to be supposed that in time of war all buoys and similar aids to navigation will have been removed, and the navigators of vessels will not rely upon such aids and will steer largely by the compass.

There are thus left as the different classes of lights, only the searching light and the illuminating light, and these distinctions are not now considered of any special importance, as circumstances may require any light to be used for either purpose.

As illustrating the methods of operation which were proposed at the time the distinctions of the different classes of lights were considered as important, attention is invited to Mimeograph No. 91, in which there is a lengthy explanation, along with a map, showing where the lights were placed and how they were intended to be used in the defenses of Hampton Roads during the maneuvers of 1905.

Briefly, it may be stated that Hampton Roads empties into the southwest corner of Chesapeake Bay. The general lines of the south shore of the bay, which runs nearly east and west, and of the west side of the bay, which runs nearly north and south, would, if prolonged, intersect at the outlet of Hampton Roads, and this point, for convenience, may be called the "corner" of the bay.

The defenses of the bay during the maneuvers were located on the south end of the west shore, on the west end of the south shore, and upon an island located at the outlet of Hampton Roads. The most easterly point that was occupied, which may be called for convenience "Willoughby," was located on the south shore of the bay about 4 or 5 miles east of the corner, and the most northerly point that was occupied, which we will call "Buckroe," was on the west shore of the bay about 3 or 4 miles north of the corner.

At each of these places, Willoughby and Buckroe, two searchlights were installed, as well as a number of light field batteries. One of the searchlights at each point was a so-called "sentinel" beam. The light at Willoughby operated normally over an angular range of about 30°, the mean of which was nearly north; and the one at Buckroe operated normally over an angular range of about 30°, the center of which was nearly due east. It was intended that the movements of these sentinel beams should be so timed that when one was at the outward limit of its arc the other would be at its inward limit, so that the beams could intersect over a comparatively small area, situated some 3 or 4 miles north of the south side of the bay and some 4 or 5 miles east of the west shore of the bay.

It so happens that at the point where the beams normally intersected there is a large shoal marked by a lighthouse. A short distance south of this shoal there passes the main entrance channel from the ocean, while between the shoal and the west shore there is a secondary channel which can be used by small boats.

With this arrangement of sentinel beams, it is evident that no vessel can enter the area within the beams without passing through one of them, and therefore, supposedly, being seen.

The other lights at each of these positions, Willoughby and Buckroe, were installed approximately 100 yards outside of their respective sentinel beams and were intended to be used as searching lights, each moving back and forth in the angle, approximately equal to a right angle, between the shore and its sentinel beam. The object of these lights were; first, to act as a protection against a vessel that might come up but stay just outside of the sentinel beam, and, second, to give, if possible, earlier notice of the approach of the enemy.

The light gun batteries were installed at these points and were intended, of course, for the protection of the searchlights from guns in small boats.

Inside of the sentinel beams and located at advantageous positions among the principal batteries of the defense, were installed the illuminating lights which were intended to be kept dark until it was nown the enemy was approaching.

One only of these interior lights was intended for any function other than illumination and that was the inmost light. This was so located that its beam could be turned across the channel to Hampton Roads without intersecting the beams of other lights. This beam passed over the supposedly mined field. It was intended, should occasion arise, that this light might be kept in operation over the mined field as a searching light to detect any small boats that might attempt counter-mining or cable-cutting operations.

The normal use of this system of searchlights was as follows:

If either of the searching lights which were operating outside of the sentinel beams detected the presence of an enemy this light was to continue to illuminate the enemy as he approached. It would continue to hold this vessel in its beam as the vessel approached the normal range of the sentinel beams. Under these circumstances the sentinel beam was to be allowed to leave its normal arc of action until its beam also illuminated the enemy's vessel, but this movement was to be made very slowly and carefully so as not to overlook anything else. As soon as the sentinel light had picked up the approaching vessel, the searching light was left free to resume searching.

The sentinel beam would then continue to illuminate the vessel as it passed inwardly, until it had nearly reached the inward limit of the normal range of the sentinel beam. As soon as this happened, one of the regular interior illuminating lights was to be brought into action and to be used to illuminate the enemy. As soon as this illuminating light picked up the vessel, the sentinel beam was to go back to its regular duties.

Should another enemy appear and be caught by the searching light, it would be passed on to the sentinel light, by this, to an illuminating light, and so on.

It seems to have been expected at that time that it might be possible to illuminate at one time and to use as targets almost as many of the enemy's vessels as there were searchlights, but one of the things that was taught by these maneuvers was that in any practicable distribution of searchlights among batteries there is a very small limit to the number of vessels which can be satisfactorily illuminated at one time without requiring either the range-finding instruments or the sighting telescopes on the guns to look through one or more beams.

Another lesson was that whatever classification may be made of these lights as, battle commander's lights, fire commander's lights, and battery commander's lights, nevertheless, the operation of all of the lights must be under the close control of some one general commander; otherwise, the crossing of beams and interference with observation stations is certain to occur. Furthermore, it was clearly shown by the maneuvers that the number of searchlights that can be used satisfactorily and simultaneously in a limited area is itself quite limited.

Still another lesson was that where there are a number of lights in operation in any one area, the control apparatus for any one searchlight must, in general, not be very far from the light itself, otherwise the man at a controller may be unable to identify his beam from the others that may be in operation.

In this connection, the following extract from the report on searchlights during the 1905 maneuvers (mimeograph No. 91) may be interesting:

> In connection with the subject of the distant control of searchlights, it appeared to me during the exercises that, except in certain limited cases, very distant control is not advisable. For searching lights that are comparatively isolated, and whose beams are not liable to be confused with those of other lights, long-distance control may be desirable, but for illuminating lights, especially when a number of them are grouped within a comparatively small area, this is not true. Under certain atmospheric conditions, it is very hard, at a distance, to distinguish one beam from another, or to tell accurately by which beam a target is illuminated. During one of the preliminary drills, one officer mistook for his own another beam, and in trying to maneuver the latter, and attributing his difficulty to some defect in his own controller, he unwittingly

traversed his own beam until it extended directly across the line of sight of some of the observing stations, and for a while, put these stations out of action. With more practice, such an accident might not have been possible, but there were other incidents that convinced me, that, with many lights in simultaneous operation, each operator must not be too far away from his own light to easily and clearly distinguish his beam from all others.

THE LOCATION OF SEARCHLIGHTS.

Searchlights are, in general, installed with one or two objects in view: First, to give notice of the approach of an enemy, and, second, to illuminate the vessel so that it can be used as a target for the guns.

In order that our guns may be enabled to keep the enemy as far away as possible, it is desirable that his presence be detected before he comes within the range of the guns.

However, the range of our guns exceeds the effective range of our searchlights. This has always been true and is true now. When, about 1905, the effective range of our major caliber gun was supposed to be 12,000 yards, the best searchlights which we then had were effective under ordinary conditions at 8,000 yards only. At present the effective range of our searchlights has been increased to possibly 15,000 yards, but in the meantime the effective range of our guns has gone up to 30,000 yards or more.

If our searchlights are to be able to illuminate the area near the extreme range of our guns, the searchlights must be placed well in advance of the guns, that is, toward the harbor entrance from the batteries. This, however, must not be done to such an extent that the searchlights are so far in advance of our guns as to leave them subject to destruction by fire from the enemy's ships, which are beyond the range of our batteries.

In fixing the locations of searchlights with respect to batteries and observation stations, it should be noted that the searchlights must not be placed so that the beam when used in any probable direction will illuminate the battery or range station so it can be seen by the enemy. Furthermore, the searchlight must be placed far enough from the batteries so as not to be injured by the blast effect of the guns. With the old standard form of searchlight, the strips of the front door were quite sensitive to severe blast effect, but this difficulty has been largely removed by the introduction of high intensity lights which require no front door.

The problem of locating searchlights with reference to observation stations and the sighting telescopes of the guns is made difficult by the fact that it is hard to see through one searchlight beam a target illuminated by another beam. If the target be not very distant and be very brightly illuminated, it can, of course, be seen through the beam of another light, especially if that beam be quite diffused, but where the object illuminated is very distant and the illumination is very dim, it can not be detected through another beam. As a result, an observer on one side of a searchlight beam can see almost nothing of what is happening on the other side. Consequently, an observer situated between two beams that cross in front of him has his field of vision, for practicable purposes, confined to the area between the two beams.

Another important matter in this connection is that, for essentially the same reason that causes the difficulty mentioned in the preceding paragraph, an observer close to a beam can see but little of the objects illuminated by it. The reason for this is evidently that he is looking almost straight down the length of the beam and, therefore, is trying to see an object through the maximum length of the beam. If, however, he is at considerable distance to one side of the searchlight, his line of vision to the illuminated object will enter and pass through but a small length of the beam and that will be where the beam is most diffused. The minimum distance to either side of the searchlight at which the observer should be placed to obtain good vision, depends to a large extent upon the intensity of the beam and upon the atmospheric conditions. In general, however, it may be said that in order to see well an observer should not be less than 150 yards to one side of an old-style 60-inch light and 200 yards to one side of a high intensity light.

If the guns are to be fired by case 3 at a target illuminated by a searchlight, the observer at the sighting telescope can see well enough if the searchlight be on either side of the gun, provided it is not within the minimum distance previously given. Consequently, for case 3 firing there would be no difficulty in having a searchlight for every battery and all in simultaneous operation, provided the intervals between the batteries were sufficient to permit all the searchlights to be installed more than the minimum distance from the nearest guns.

When, however, searchlights are to be used in connection with a horizontal position finding system, the searchlight locations must be chosen largely with reference to the positions of the base end stations. If there is but one base line, or if the same target is to be used by all the guns, the searchlight may evidently be located either between the base end stations or on the outside of either. If, however, more than one target is to be illuminated at the same time, it is evident that the searchlights must not be between the base end stations, for if this were true one, at least, of the base end stations would have to look through one of the beams at a target illuminated by the other. Consequently, in any harbor the number of targets which can be simultaneously illuminated for use with horizontal position finding is exceedingly limited. Consequently, it would appear that the policy will have to be to concentrate the entire armament on a very few targets at a time, destroying these before attempting to fire at other targets.

Incidently, also, it should be noted that in the early days of searchlight use, when the ranges at which it was expected to provide illumination were quite small, it was proposed to mount the searchlight very high and direct its beam, not at the object to be illuminated, but over that object. Such a beam is, of course, reflected in the water and makes the water apparently luminous itself. Dark objects are said to show up well in this illumination. This was tried and for very short distances was found to work well, but for longer distances it was of no avail because, as has been stated, even when the beam is as concentrated as possible and is turned directly on the target the illumination is barely satisfactory.

Similarly, other persons advocated the use of searchlights on the opposite side of a harbor entrance from the observer, the idea being that the searchlights would be thrown on or nearly on him. This would throw the dark side of the object toward him, but as the object passed across the light it would be strongly silhouetted against it and therefore would be plainly visible. This also was tried and at very moderate ranges was found to work quite well, but it was found to be absolutely valueless for use at a distance.

Height of Searchlights.

The question of the height at which searchlights should be placed is, of course, but one item in the question of location.

In the early days of searchlights, when the ranges were small, it was considered by some experts that they should be mounted so low as to make it impossible for any vessel or boat to sneak through close to the shore under the beam. This extreme lowness of light was soon found to be unnecessary, for under any searchlight beam, unless it be mounted at an extreme height, there will almost always be sufficient diffused light to illuminate a boat.

For illuminating a very distant target, all the available power of the searchlight is necessary. Close to the water's surface the transparency of the atmosphere is usually less than higher up, due to the haze or spray, and this haze is considerably increased when there is a wind or the water is rough or choppy. It is therefore desirable that the searchlight beam, for as much as its length as is possible, should pass through the higher and more transparent air. In other words, a searchlight should be mounted as high as possible.

In a few locations along our north Atlantic and Pacific coasts and in the Tropics, high sites can be found that are suitable for searchlight use; but unfortunately, along our middle and south Atlantic coast, and along the Gulf of Mexico, the shores are all low and the mounting of searchlights at an elevation presents considerable difficulty.

Attempts were first made to accomplish this by means of fixed towers which would raise the lights approximately 60 feet above high water. In a few, but very few, locations it was possible to build these towers in the vicinity of woods so that they could not easily be seen. In most places, however, woods and other natural hiding places were not available and the towers were most conspicuous. Not only did this make them much more liable to destruction by gunfire, but it made it possible for an enemy during the daytime to note the location of these towers, plot this location on his charts, and then, at night, when the searchlights were in action, they could be used as aids to navigation in much the same way as our large seacoast lighthouses.

The searchlight towers which were built were sometimes constructed of timber and sometimes of steel. In both cases they were of skeleton construction, consisting of four uprights and the necessary horizontals and diagonal bracing. The feet of the uprights were usually set in concrete blocks on the corner of a square about from 16 to 24 feet on a side, depending upon the height of the tower. The platform at the top was usually about 12 feet square and was roofed over, while the sides were made at least partially removable so that they could be taken out of the way of the beam. Usually the center of the floor of the platform was made as a removable trapdoor so that the light could be pulled up to the platform or let down if desired. The stairway was usually inside of the uprights. In a few cases the skeleton steel framework of an abandoned fire-control tower was utilized for this purpose, the necessary alteration being made at the top.

The next recourse was to disappearing towers which, during the day, would be lowered out of the enemy's sight behind a sand hill or parapet, and which, at night, would be raised into the working position, with the searchlight on a platform high above the sea and ground. Three types of such towers have been tried; one based much upon the same principle as in the Scherzer rolling-lift drawbridge, one based upon the somewhat similar Strauss Bascule drawbridge, and the third upon the principle of the simple counterweighted beam or lever. Of the three, the last named seems to be the most efficient and has been tentatively adopted as a type. In the original installations of all three of these towers, the attempt was successfully made to raise the light about 60 feet above the ground. Drawings of all these types are in the office of the Chief of Engineer and will undoubtedly be made available for the use of officers.

Not only must a disappearing tower raise the searchlight up to the proper elevation, but it must hold it there firmly and on a perfectly horizontal platform. If the tower is so light that the wind causes it to vibrate, the searchlight beam will vibrate and this is almost fatal to distant observation. The platform on which the searchlight rests when lifted, must be perfectly horizontal because, if not, the motion of the beam in azimuth will have the tendency to raise or lower the beam, requiring constant adjustment in the elevation. This constant adjustment seriously interferes with vision.

The greatest difficulty that has been heretofore met with is in the great weight of the standard seacoast light, between 6,000 and 7,000 pounds. This difficulty will be largely reduced in the future because of the great reduction of weight in the modern dish-pan searchlight. (A satisfactory control mechanism has not as yet been adopted to this form of light, but it is believed, even when this is added, the weight of the dish-pan searchlight should not exceed one-fourth or one-fifth of the weight of the older light.)

Concealment and Protection of Searchlights.

If a searchlight is hit by an enemy's projectile it may be destroyed or seriously injured. In the daytime a searchlight is of no use whatsoever. Consequently, the safety of the searchlight when not in use would point to its being thoroughly protected in the daytime. For this reason, in many places, searchlights are mounted on small cars which can be moved back and forth on a few feet of track. At night, of course, they are moved to an operating position, but in the daytime they are rolled into shelters built behind conveniently situated hills or into rooms of batteries or other parts of the defensive works. Preferably, of course, these shelters should protect the searchlights not only from the direct fire of the enemy's projectiles but also give sufficient overhead protection. The latter is not always possible, but protection from direct fire by putting a searchlight behind a parapet is much better than no protection at all.

If protection is not possible, the next best thing to do is to conceal the lights, not only for the sake of keeping them from being fired at, but in order that their positions may not be spotted by the enemy during the daytime and the lights be used by him at night as aids to navigation.

In connection with the concealment of searchlights, quite a number of devices have been used at various places. Where searchlights have been located on the tops of hills, arrangements have been made by which they can, in the daytime, be lowered down into excavated shelters. Sometimes the searchlight is lowered vertically and sometimes it is rolled down an inclined plane, counterweights being used in both cases. Where the searchlight drops down vertically, it is usually mounted on a platform having a roof which, when down, forms the roof of the shelter. This roof must be, if possible, so arranged as not to be visible either from horizontal view or from an airplane. Where the searchlight goes down an inclined plane, it usually moves into a more or less bombproof shelter.

In other places, when searchlights are to be used along a thickly settled beach, plans have been devised for building as a searchlight station, a structure which, from the sea, will appear exactly similar to the beach cottages. The searchlight is to be placed in the rear part of a cottage and is to be so mounted that it will appear above the roof of the cottage. The front rooms can be filled with sand and thus give considerable protection to the searchlight.

Officers interested in the subject should obtain for inspection plans of the disappearing installations at Diamond Head, Honolulu; Tennessee Point, San Francisco; and Los Angeles.

As a method of providing protection for the searchlights, not only during the daytime, but even when in operation at night, it has been suggested that the searchlight and its mechanism, which is quite expensive, might be kept behind a parapet and throw its beam upon a plane mirror at one side of the parapet which would reflect it to the target which it was desired to illuminate. This means, of course, the additional expense of a plane mirror and its mounting, and this plane mirror would, of course, require the distant control mechanism. However, it was considered probable that the cost of the plane mirror would be so much less than that of the searchlight, and that the plane mirror would be so much easier to replace, that the scheme might be advisable.

As at first suggested and tried, the plane mirror was essentially on the same level as the searchlight and changed the direction of the beam in the horizontal plane only. Later, it was suggested that the same expedient might be utilized, not only to give protection to the searchlight proper by leaving it behind a parapet, but also so as to elevate the beam to a sufficient height.

This could be done either by two mirrors or by one. In the former case, the searchlight would throw its beam horizontally and this beam would be reflected into a vertical position by a plane mirror set at an angle of 45°. At the proper elevation, and on top of a sort of skeleton tower, there would be placed another mirror set also at an angle of 45°, which would change the vertical beam back again to a horizontal one. By rotating this upper mirror, or rather stand, in azimuth, the beam could be sent in any desired horizontal direction. This method has the disadvantage of a double loss of light due to double reflection.

The other method was to place the axis of the beam in a vertical line, in which case the upper plane mirror only would be needed. This would require the reflection of the beam at one mirror only.

With a view to determining the possibilities of the use of plane mirrors with searchlights and, incidentally, the loss of illuminating power by this reflection, experiments have been made in the last year or two. As a whole, these experiments have been discouraging. Plane mirrors of proper size have been exceedingly difficult to obtain and the attempt to use a composite mirror made up of smaller mirrors has met with failure, owing to the practical impossibility of insuring that the different individual mirrors would all be in the same plane or in parallel planes. Furthermore, the loss of illuminating power by this reflection has been shown to be extremely great, but to what extent this large loss of power has been due to defects in the plane mirrors used, and to what extent it is inherent, has not yet been determined.

REINFORCING LIGHTS.

During the maneuvers of 1905 it was simultaneously suggested by several persons that for use at extreme distances where the illuminating power of searchlights was small it might be possible to increase the illumination by the use of what may be called "reinforcing lights"; that is, of several lights thrown simultaneously on the same target so that their combined effects might make the target visible when it would not be sufficiently illuminated by one beam only.

This was attempted but was found not to work well for a number of reasons which would appear to be almost inherent.

Where a single searchlight can illuminate a target so that it can be seen only dimly and not with sufficient distinctness to be observed by position finding telescopes, the addition of another light does indeed increase the apparent illumination of the target and make it possible to use the telescope. Where the target is fixed in position, this works fairly well, but when it is attempted to keep two beams on a distant moving target, great difficulties are encountered. When, by a decrease in the illumination of the target, it becomes evident that it has gotten out of one beam, it is impossible to tell which beam is still illuminating it and which is not. In an attempt to get both beams back on the target, the operators are just as likely to move from the target the beam that is on it, thus leaving it in total darkness. By having the controllers of both beams in the same station and operated by the same man, it may be possible for a very well-trained operator to keep both beams on the target. But for general use it would appear that the scheme is impractical, even when the range is not too great to leave the object slightly visible when illuminated by one beam only.

For finding a target so distant as not to be visible at all when illuminated by one beam, the scheme is absolutely useless.

RESERVE SEARCHLIGHTS.

Up until the time when the United States became involved in the World War, the project for searchlight installation of all our defenses was so far from completion that but little attention could be paid to the question of reserve lights, but the possible availability for domestic use of a large number of searchlights purchased for operation abroad has, since the armistice, made it necessary to consider this question. A searchlight is, of course, vulnerable and can be destroyed. It is exceedingly useful, and if destroyed, it should be replaced almost immediately. This means that there should be a reserve light available. If a reserve light be kept close to the light in operation, it may be destroyed at the same time and safety points to its being kept some little distance away. The question then naturally arises as to whether it would not be well to employ the reserve searchlight so that it might be available not only as a reserve but as an additional light.

Taking this into consideration, it would appear that it would be well, where it can conveniently be done, to have two searchlights placed in fairly close proximity one to the other, both so installed as to be put into use quickly when needed. Normally, one light only would be used. If destroyed or put out of commission for any reason, the other light would take its place. In an emergency, both could be used.

In places where it is probable that both searchlights would be useful and might be used simultaneously for a considerable portion of the time, it would appear well to have a third light in reserve.

The same principle that would indicate the practicability of reserve searchlights would indicate the desirability of reserve searchlight electric plants. The policy where there are two searchlights located in fairly close proximity, would be that each should have its separate generating plant and that there should be a third plant somewhere in the vicinity which could be used as a reserve for either.

Spare Mirrors.

The most vulnerable portion of the modern searchlight is the glass mirror which may be broken from many causes. This was recognized a number of years ago and as soon as it became possible to obtain in this country searchlight mirrors of domestic manufacture, the policy was adopted of purchasing reserve mirrors. Some of these reserve mirrors were to be normally kept in stock in the main Engineer depot, a few others in minor depots in various sections of country, and still others in our coast defenses. The number of reserve mirrors to be kept in each coast defense was to be not less than one-third of the number of each size in actual use. Such a distribution was in progress at the beginning of the war but it was necessarily interrupted by the demand for field searchlights abroad.

Portable Searchlights.

Before the installation of searchlights had been in progress for many years, it became evident that a number of the most suitable locations were outside of the limits of the coast forts and were on private grounds. To attempt to maintain searchlights in times of peace in these places would be difficult and expensive, and it was therefore decided that it would be desirable, if possible, to make some of our searchlight outfits portable so that they might be taken to these desirable outlying sites for drill purposes or during maneuvers, as well as in time of war.

An attempt was therefore made to develop portable searchlights and a number of 36-inch sets were actually built. These were utilized later in the portable searchlight brigade, which was sent from point to point in the country for the purpose of determining by trial the desirable locations for searchlights. These sets consisted of two units, the generator unit and the searchlight unit. They were horse drawn, exceedingly heavy, and could be moved only with difficulty, especially in sandy soil. To move them for a short distance and put them in place was possible but they were not portable in the sense that they could be rapidly put into position and later withdrawn if exposed to too hot a fire.

In many respects the machinery of these so-called portable outfits was quite crude and practically all of them have since been scrapped.

Prior to the Japanese-Russian War the use of searchlights in military operations had been advocated almost exclusively in connection with seacoast defense, and their use in field operations appears not to have been seriously considered. During the siege of Port Arthur, however, searchlights proved their usefulness in connection with such operations, and shortly thereafter it was decided to be advisable to introduce portable searchlights into the trains of our mobile army for use with Field Artillery. Searchlights for this purpose must, of course, possess considerable mobility, in fact, mobility might be almost said to be the prime desideratum.

Prior to the entrance of the United States into the World War, three sizes of such lights had been developed, a 24-inch horse-drawn light for use with horse-drawn Artillery, a 30-inch motor-drawn light for use with motor-drawn Artillery, and a 36-inch portable light for siege use. Very few of these had actually been manufactured, but as soon as funds became available, contracts were placed for the manufacture of a number ot them. In the meantime, development work was in progress and this proceeded so rapidly that almost before searchlights of any size could be delivered in quantity, the improvements and developments that had been made rendered them obsolete.

The different types that were tried are too numerous to describe, but there were finally developed two serviceable forms of portable 60-inch searchlight outfits. In one of these forms, each set consists of two units, a generating unit and a searchlight unit. The generating unit consists of a standard 25-kilowatt electric generator mounted in an automobile truck which can be moved rapidly from place to place. A 60-inch searchlight mounted on a somewhat similar truck completes the outfit.

Later, a still more portable set was developed, consisting of a single unit. The searchlight pertaining to this unit is of the dish-pan type, mounted on a light car with rubber tires, the whole weighing but 650 pounds. This is loaded by a portable ramp into an automobile truck, the engine of which propels the truck when desired, or furnishes electric power for operating the searchlight when the truck is at rest. The truck contains, in addition, a considerable length of cable on a reel, so that the light on its light rubber-tired car can be moved a considerable distance from the generator before being put into operation.

The last two kinds of portable lights mentioned were developed primarily for use in anti-aircraft work and were therefore not provided with distant control mechanism, since it was found for anti-aircraft work the control of the searchlight had to be done at the light and by levers.

Before this light will be serviceable for seacoast use, it is probable that distant control mechanism will have to be added. This is believed to be perfectly possible, although it will increase the weight and will to some extent affect the portability. Being intended for use in anti-aircraft work, no attempt was made to elevate the light above the ground. For seacoast use, the searchlights must be raised, and therefore steps are in progress looking to the development of a slightly heavier automobile searchlight outfit which contains a collapsing or disappearing tower by which the searchlight can be lifted to a height of approximately 40 feet. Up to the present, this outfit has not yet proved practicable, but the design is said to possess considerable promise.

In the meanwhile, and for use in harbors where there are available railroad tracks, a railroad searchlight outfit has been developed. This outfit consists of two units, one containing the generating set and accommodations for the detachment, and the other the searchlight mounted on an elevating tower. This outfit has recently been completed and is reported to be a success.

ANTI-AIRCRAFT SEARCHLIGHTS.

The most important development in searchlight matters during the recent war was in connection with anti-aircraft defense. The lights formerly in use had been designed to operate with their beams horizontal or at only a slight elevation above the horizontal, this elevation being made use of in signaling and for tactical reasons. A searchlight would be put in operation with its beam elevated so that the commanding officer might be certain that the beam he had ordered into use had received the order. Similarly, in order that he might know positively that his instructions for the extinguishing of a light had been carried out, the beam would first be elevated and then would be occulted while in the elevated position. There was, therefore, a comparatively small limit to the elevation at which the older searchlights had to be operated.

When an attempt was made to move the beams to a greater elevation, the regulating apparatus ceased to work. Further, under such conditions, the mirrors were apt to be injured by fragments of carbon falling upon them. For following aircraft, however, it is essential that the searchlight beams go all the way to the zenith or possibly, in a few cases, beyond the zenith. An attempt was first made to obtain this high elevation by the use of reflecting plane mirrors. These proved inadequate for the purpose. Fortunately a lamp mechanism was soon developed which would work with the beam in a vertical position, and it was found to be possible to add a screen that would protect the mirror from the dropping of carbon fragments. The final result of these developments was the portable dish-pan light described above.

As far as anti-aircraft searchlight defense is concerned, the arrangements to be made at seacoast defenses do not differ from those in the efense of cities. Consequently, the matter will not be treated further here.

OTHER METHODS OF BATTLE-FIELD ILLUMINATION.

In the early part of the World War attempts seem to have been made to use searchlights for field operations. These soon ceased and as far as is known to the author searchlights seem to have been practically restricted during the latter part of the war to anti-aircraft use only.

Searchlights having proven themselves not specially satisfactory for battle-field illumination, attempts were made to light up the foreground in front of the lines by means of flares. Some of these were dropped from rockets, some were fired from rifles, and some from specially designed mortars. These, however, were of comparatively small range and lit up the ground only a short distance to the front.

It is understood, however, that fairly successful attempts have been made to inclose a flare and parachute in the projectiles of guns as large as 5 inches and 6 inches. The guns are fired at quite a high angle of elevation and the projectiles are fitted with a time fuse which explodes the mat the proper time. The explosion is of such a character as merely to blow out the base of the shell and to set the flare and parachute free.

If the above idea proves to be practicable with guns of fairly long range and the flares can be made so as to burn for a considerable time, it would look as if they might be adopted in seacoast defense for lighting up the sea at extreme ranges. As to whether or not this is possible, only the future can show,

FUTURE DEVELOPMENTS.

The rapid advance that has been made in the last few years in the range of heavy artillery has, in spite of the improvements in searchlights, placed the range of seacoast and naval artillery far beyond the range of any searchlights that can be made. Consequently, long before a hostile vessel can get within searchlight range it will have come within the range of the artillery, both its own and that on shore.

Consequently, it would appear that reliance upon the beams of searchlights for informing us of the approach of an enemy's vessel is now a thing of the past. If we are to learn of such approach at or near the extreme range of our guns, we must make use of other devices and must restrict our searchlights in all probability to the illumination of vessels whose presence has long before been learned by these other means.

Several years ago the writer suggested to the Chief of Engineers and to the Chief of Coast Artillery that in the future reliance for early information as to the approach of an enemy's fleet could well be obtained by picket boats. It would appear possible to select, in and around the entrances to many of our harbors, certain picket-boat locations, and to lay to these locations telephone cables the inshore ends of which would be connected to our telephone system. To the outer ends of these cables would be attached buoys which would float a short distance below the surface and would, therefore, not be visible to the enemy. About dusk or shortly afterwards, the picket boats would go out to their proper locations, locating themselves by ranges temporarily placed on shore. When in or near their positions, the men in a boat would grapple for the buoy and, having found it, the end of the cable would be hauled into the boat and telephone communication established with the shore. Such communication would be maintained until daybreak, when the buoys would be thrown overboard and the boat would return to the harbor.

It has been suggested that these boats might be fitted with submarine "ears" now used under certain conditions on vessels for picking up the direction of submarine fog signals. It is understood that these "ears" are sensitive enough, when used from a ship at rest, to give an indication of the approach of a vessel quite a number of miles away, and at the same time to give a fairly close approximation of the direction of the approaching object.

Upon hearing an approaching ship the picket boat would at once telephone to the shore, giving the azimuth of the approaching ship from the boat. In general, the picket boats should be so close together that an approaching ship could be heard by more than one boat, and the relative azimuth indications from the boats would show the location of the ship and should later render possible the plotting of its course.

If desired, the ship could be fired on and although this fire would probably not be very effective, it would no doubt warn the ship that its presence was known and probably cause it to withdraw.

It is understood also that experiments are under way tending to lead to the development of a form of sensitive anchor which by electric-magnetic means will give notice of the approach of a vessel and its approximate direction. Should this develop into a practicable apparatus, it will go far toward solving the problem of the distant detection of an approaching enemy.

CHAPTER XIV.

SUBMARINE MINING.

This chapter will be devoted to a brief recital of the connection of the Engineer Department with submarine mining.

During the Revolutionary War some attempts seem to have been made by the Americans to destroy British war vessels anchored in our harbors by the use of explosives attached to the bows of submarine or partially submerged vessels. Somewhat similar attempts were repeated by the Confederates during the Civil War, and in at least one case, such attempts were successful. In addition to using submarines, the Confederates tried to close some of their harbor channels by anchoring in them explosive mines and apparently succeeded to the extent of sinking one of Admiral Farragut's monitors when, in the summer of 1864, the admiral forced his way into Mobile Bay. However, the question as to whether the monitor was destroyed by a submarine mine planted by the Confederates or by other means is one concerning which historians are not in thorough accord.

The attempt of the Confederates to close some of their harbors by submarine mines, and the moral effect which the supposed presence of these mines seems to have had upon our naval officers, drew the attention of the Federal Government to the importance of mines; and their use was, in 1865, recommended by the Board of Engineers. As a result, when shortly after the Civil War, the Engineer School was established at Willetts Point (now Fort Totten, Long Island, N. Y.), the development of a submarine mining system was assigned to that school. Gen. Henry L. Abbot, Corps of Engineers, was assigned to duty as commandant of the school and the development of our submarine mining system was largely due to his untiring efforts. In the nearly 20 years during which he was connected with the school he brought the system to such a high state of development that the improvements that have been made since have been almost exclusively in details, and in those details where improvements have been made possible only by recent discoveries and by the development of electrical and mechanical appliances unknown at the time the development of the submarine mining system was under the supervision of Gen. Abbot.

Abbot System.

When Gen. Abbot was relieved from duty at Willetts Point about 1886 the system that had been developed by him was briefly as follows:

The mines used were of two kinds, ground mines and buoyant mines. The latter were those commonly used, and even when ground mines were used they frequently had attached to them buoys which when struck by a vessel would cause the mine to explode.

The mine case was made of steel approximately one-half inch in thickness, the most common form consisting of two hemispheres 32 inches in diameter. These hemispheres were pressed out of flat steel plates. At the same time there was turned up along the edge of the hemisphere a rim an inch or two wide. The two hemispheres of a mine case were firmly welded together along their rims and this formed a spherical case, 32 inches in internal diameter. At the top of the mine there was fastened a fixed ring by which the mine could be raised or held up, and at the bottom there was left an opening into which could be screwed through a water-tight joint, the so-called compound plug. This opening was loosely covered by a removable cap in which the joint between the cable and the insulated wire entering the mine was protected. To three points symmetrically situated on the lower hemisphere were welded three long bales which, at their lower ends, were united in a ring to which could be attached the anchor ropes. The anchor ropes used were made of steel wire and were shackled at their lower ends to heavy anchors.

The compound plug which was screwed into the bottom of the mine case consisted of a water-tight entrance for the insulated wire, a chamber to hold the priming charge and fuses, and above this chamber a combined circuit closer and circuit regulator.

The insulated wire after passing through the water-tight entrance in the base of the compound plug entered the priming chamber. Here two fuses in series were placed in the circuit which ended at a terminal post on the circuit regulator. The priming charge of dry gun cotton was placed in the priming chamber, around the fuses.

The circuit regulator was intended for firing the mine by "judgment"—that is, without its being hit and while the current still remained open at the circuit closer. The main essential parts of the circuit regulator were a high resistance coil of wire and a small already polarized permanent steel magnet. Normally, the electric current coming from the shore passed through the fuses in the priming chamber, thence through the high resistance coil to the metal walls of the compound plug, and thence through the mine case to "ground." The resistance of the coil was so great that this current was much too small to affect the fuses in any way. Moreover, the direction of the current was normally such that the magnetic action induced in the coil was of such a character as to repel the permanent magnet. If, however, the direction of the current was reversed, the magnetism induced in the coil was also reversed and the small permanent magnet was attracted. In moving, it short circuited the high resistance coil and greatly augmented the strength of the current.

The circuit closer part, intended for contact firing, consisted essentially of a small metal ball resting in a little hemispherical cup-like hole. Normally, the electric circuit was broken here, but if the mine was struck sufficiently hard or was tipped sufficiently far, the metal ball would roll up along the side of its cup until it touched one of a number of metal springs, thus making an electric connection and short circuiting the high resistance coil of the circuit regulator.

The mines were connected with the shore by insulated armored electric cables lying on the bottom. At or near the shore these cables passed in through cable conduits to so-called mining casemates which contained the operating apparatus. All the joints of these cables were very carefully insulated, so that after a mine was put in place there wâs a continuous insulated electric circuit passing from the operating apparatus in the casemate, through the core of the cable and the various junction boxes, into the priming charge chamber of the compound plug. Here the circuit, still insulated, passed through two fuses and to an insulated attachment on the base of the circuit regulator where it divided into two parallel branches, one passing to ground through the high resistance coil of the circuit regulator and the other attempting to pass through the circuit closer.

In the operating casemate were two voltaic batteries; a so-called signal battery consisting of a few cells of the Daniel type similar to those used in telegraph offices, and a firing battery composed of some 300 "Lelanché" cells similar to those used in electric bell circuits. These two types of cells were chosen because, at that time, the Daniel battery was the most efficient then known for use on closed circuits, and the Leclanché cells for use on open circuits.

The signal battery was normally kept in circuit with the mines, and caused a slight current to pass through the cables and the high resistance coils of the circuit regulators. This current was measured when the mines were planted and from time to time thereafter, supposedly at least once a day. The constancy of this current gave evidence as to the good condition of the mine and its connections.

If the mine was struck and tipped by a passing vessel or in other ways the ball of the circuit closer would make connection, short-circuiting the high-resistance coil and largely increasing the current passing through the cable. This increased current would then be sufficient to work the operating apparatus in the operating box of the casemate, but was not enough, if only the signal battery were in the circuit, to fire the mine. However, if the firing battery also was in circuit, or was brought into circuit by the mechanism of the operating box, the fuses would be fired and the mine exploded.

To fire the mine by "judgment" it was necessary to connect in the firing battery, but in the reverse direction. The voltage of the firing battery passing through the high-resistance coil of the circuit regulator was not of itself sufficient to fire the fuses; but if this current passed through the circuit regulator in the reverse direction it reversed the magnetism of the coil, drew over the small permanent magnet, and short-circuited the high-resistance coil, thus causing an increase of current sufficient to fire the fuses.

Such a mine was harmless unless the firing battery was turned on. With the battery out of circuit the mine might be struck by a vessel with safety to the vessel though not necessarily with safety to the mine. However, if the firing battery was in circuit the mine would explode upon contact, and it could, by reversing the firing battery, be fired at any desired time even without being struck.

In the electric system the so-called "single wire" was used, the earth and water being utilized as the return circuit. The inner end of whichever battery was in series with the mines was grounded through a wire leading into the casemate, and the outer end of the circuit was grounded through the mine case, which was submerged in sea water.

The mine was usually moored so as to float at low tide and in a slack current about 5 feet below the surface. Had it been closer to the surface it could have been seen from a distance and could probably have been destroyed by artillery fire. As the tide rose the water, of course, would rise higher above the mine, but fortunately in all the harbors of our country the tidal fluctuations are too small to place the mines so deep that they could be passed over at high tide without being struck; that is, unless the mine had been depressed by the action of currents.

When a mine is moored in water where there is a strong current it will, of course, be pushed sideways by the current, thus causing the anchor rope to assume an inclined position until an approximate equilibrium is attained between the depressing effect of the current and the buoyancy of the mine case. With the same strength of current, and consequently the same angular displacement of the anchor rope, both the horizontal movement and the vertical depression vary proportionately with the depth of the water. For evident reasons the mines, when thus depressed, must not be permitted to sink so low that at high tide vessels might pass over them without touching them.

Furthermore, it is advisable that the horizontal movement be restricted within as narrow limits as possible. Mines are planted in regularly located groups with intervals so small that it is practically impossible for a vessel to pass through a group without striking at least one mine. Theoretically, of course, the current effect on mines planted fairly close together should be such as to give them equal and parallel displacements, but actual experience shows that this is not always true, and that the irregularities in currents are frequently so great that with any considerable horizontal displacement the intervals between the mines may become extremely irregular, leaving gaps through which a vessel might possibly be able to pass.

It was therefore considered desirable, even for mines to be fired by contact, that the horizontal displacement be kept small. For mines to be fired by "judgment" this is even more important. The effective radius of action of a mine is comparatively small, and for certainty of effect in "judgment" firing it is essential that the mine, at the time it is fired, should be quite close to where it was expected to be. Of course the displacement caused by a current might be estimated and allowed for, but such an estimate must in any case be but little more than a guess.

Fortunately, it was possible to diminish to a considerable extent the movements of the mine by the simple expedient of increasing the size of the mine cases. The pressure of the current varies, of course, with the area of the surface exposed to the current, while the upward or buoyant force varies with the volume of water displaced. As a body increases in size its volume increases in greater ratio than its area, so that the larger the mine case the greater the ratio between the buoyant force and the deflecting force and the less the angular deflection of the anchor ropes; consequently, the smaller the horizontal displacement and the vertical depression of the mines.

This fact was recognized and several sizes of large mine cases were designed, the largest having a volume equal to that of a 46-inch sphere, or approximately three times that of the regular 32-inch sphere. However, in order to secure as far as possible uniformity in details this increase in size was made not by using larger spheres but by keeping the same top and bottom hemispheres and inserting between these two hemispheres cylinders of the same diameter as the hemispheres and having lengths sufficient to give the proper volume.

The larger mines were intended for use in deep water or where the currents were strong, as for these locations the depression of the larger mines would not be as great as if the standard 32-inch mines were used. However, it had to be recognized that there might be places where a large tidal variation, or the existence of very strong currents, would cause even the largest mines to sink so low, either at high water or when the current was strongest, that vessels might pass over them with comparative immunity. For such a locality it was proposed to plant in comparatively close proximity two sets of mines; an outer set at such depth that they would be serviceable at low water, and an interior set at such depth as to be serviceable for high water. Of course this had the disadvantage that at low water the high-water mines would probably float on the surface, where they might be seen by the enemy and would be subject to destruction by fire. For that reason these high-water mines were to be planted on an interior line that would not be reached until the outer mine line had been passed. With such an arrangement, however, an enemy's vessels might at high water pass over the low-water line of the mines and then remain between the two lines until low water, when the high-water line of mines would float on the surface and thus be subject to easy destruction. Fortunately, there are no harbors in our country where conditions are such as to require both high and low water mines, so it has not been necessary to work out the details of this system.

Theoretically, a floating mine, when the firing battery is not in circuit, may be struck by a friendly vessel without danger to the vessel. However, as was shown during the Spanish War, ship captains prefer not to pass over mines, because they seem to fear that the mine might be cut into by a propeller blade and exploded by friction. It was to avoid such trouble that the ground mine was designed.

Ground mines are intended to be used in comparatively shallow water or where it is considered necessary that our own vessels be as unimpeded as possible. Of course, ground mines were best adapted for "judgment firing," but where it was considered desirable to have them converted into a kind of contact mine, small buoys containing merely the circuit closers and regulators were attached to them. These buoys, of course, were much less of an obstruction to navigation than the full-size mines and, containing no explosive, were supposed to be safer for the passing vessels. Furthermore, if the if the buoy was destroyed it could be much more economically replaced than a mine case.

The normal arrangement of mines was in groups called "grand groups," each composed of 21 mines, or more strictly, of seven smaller groups of three mines each, called "triple groups."

In Gen. Abbot's time one of the greatest difficulties experienced in the development of the torpedo system was in obtaining suitable submarine cables, and multiple cables containing more than seven cores could not be manufactured at that time. Consequently, seven mines or seven small groups of mines were all that could be operated from a single cable. He therefore adopted the plan of having a grand group consist of seven small groups called "triple groups." The large seven-cored cable led first to a junction box called the "grand junction box." Here each of the seven cores was jointed to a single conductor cable, leading to a so-called "triple junction box." In this triple junction box the single-cored cable was connected to three single-cored cables, each leading to a separate mine, one placed 100 feet in front of the triple junction box and one 100 feet on each side. Since the grand junction boxes were planted about 300 feet apart, the 21 mines forming a grand group, extended almost in a straight line for a length of about 2,000 feet.

The joints between the single conductor cable, connecting the triple junction box with the grand junction box, and the three single conductor cables leading to the three mines were placed within a so-called "cut-out box." This was done so that each of the branch circuits might contain a fuse which would be in series with the fuses of the mine and would presumably be fired at the same time. The object of these cut-outs was as follows: Suppose one mine of a triple group to be struck by an enemy's vessel and to be fired by contact, the mine case would, of course, be destroyed, as would the end of the cable leading to the mine. The remainder of this cable leading to the triple junction box would be left, and in all probability a ragged end of the copper core would be exposed to sea water. This would cause a ground which might greatly interfere with the proper working of the remaining two mines of this triple group. To avoid this there was inserted in each branch circuit in the triple junction box a cut-out or fuse. This cut-out or fuse, being in series with the fuses of the mine and being exactly similar to them, would presumably be blown at the same time the mine was exploded, and would thus place the end of the branch circuit inside the cut-out box, where it would be insulated, instead of in the copper core grounded in the water.

Unfortunately the proper operation of this cut-out box required that it should be loaded as to be absolutely water-tight. This, of course, had to be done in the air and at atmospheric pressure, but when put to use the cut-out box was located at the bottom of the sea where the hydraulic pressure might be several atmospheres. With merely atmospheric pressure in the air inside and the heavy hydraulic pressure outside, leaks into the cut-out box were very hard to prevent.

With the arrangement just described, separate mines might be fired by contact, but when "judgment firing" was attempted all three mines of the triple group would be exploded simultaneously. This arrangement, while quite uneconomical in the use of mines has one advantage. "Judgment firing" was based upon the tracking of vessels. The process of tracking was somewhat crude, and there was always more or less uncertainty as to the exact location of a vessel and of the mines. If, therefore, "judgment firing" was resorted to only the vessel appeared to be passing through the center of the triple group, it was practically certain that one of the three mines exploded would sink the vessel.

For each grand group there was in the casemates a special operating box. This operating box consisted essentially of seven operating magnets and levers, one magnet and lever for each of the cores. At one end of the operating box there were a few simple electric switches; up one side there passed a bus bar connected with the signal battery, and up the other another bus bar connected with or connectible to the firing battery. Each operating lever had mounted on it in plain sight a number corresponding to the tactical number of the triple group. Normally, with no current on, or with only the small current due to the signal battery acting through the three high-resistance coils of the circuit regulators, the lever remained in a certain position. If, however, by the tipping of a mine and the operation of the circuit closer, or in any other way, the current through an operating magnet was largely increased, the lever was drawn over and closed a circuit which caused an electric bell to ring and throw a visible signal into plain sight near the number card of the triple group, thus giving both audible and visible notice that a mine had been struck. Incidentally this motion automatically connected firing battery bus bar to the cable leading to the mine. If this bus bar was at the time actually connected with the firing battery, the firing current would flow into the cable and explode the mine which had been struck. If at any time it was desired to fire any triple group by "judgment," the connection with the firing battery was reversed by a convenient reversing switch, the lever pertaining to the particular triple group, which it was desired to fire, was operated by hand, thus by throwing the firing current, in a reverse direction, into the cable and exploding the entire triple group.

The electric bell just mentioned not only gave audible notice of firing of a mine, it also performed another function in cutting off, for an interval of about 10 seconds, the firing battery from any possible connection with any other mine. This was done to prevent the explosion of other mines whose circuit breakers might be closed by the shock of the explosion or by the waves caused by the disturbance.

At a convenient place in the operating room there was a testing galvanometer. By the throwing of convenient switches this galvanometer was placed in circuit with the cable leading to any particular triple group. As soon as a group had been planted this connection was made and a note made of the galvanometer reading. Similar readings were supposed to be made daily and the comparison of the new and older readings showed whether or not the group continued in good condition and when it needed attention.

Incidentally, also, arrangements were made by which a so-called "sea cell test" could be applied to any triple group whose galvanometer readings indicated that it was not in good condition.

For use in connection with the sea cell test, there were exposed in the water near the casemate three separate plates, one of iron, one of zinc, and one of copper. Different wires led from each of these grounds into the casemate, and, consequently, by use of the proper one of these wires, the home ground could be made with any one of these three metals. If the home ground was a metal different from that exposed to the water at the mine, a galvanic current would be caused, due to the action of the sea water upon the two metals.

Normally the mine was grounded through its steel case, and therefore would give no current with the iron home ground but would give currents with the zinc ground or the copper ground. The top of the circuit closers was composed of zinc, so if a mine filled with water there would be in addition a zinc ground, and this would be shown by the sea cell test. Similarly, if there was an abrasion of the cable exposing the copper core, this also would be shown.

Theoretically, the use of the sea-cell test would give an indication of the cause of the trouble with a failing mine. In the hands of skilled operators it worked very well but for general use it was too delicate. It is of interest at the present time and is mentioned here because it is understood that the same essential principles were made use of in connection with the operation of the antisubmarine barrage planted by our Navy in the North Sea during the World War.

The explosive used was dynamite and in Gen. Abbot's day this was furnished in the form of a coarse powder. It was placed in a bag around the compound plug. The mine was, of course, loaded when upside down. A large bag was first inserted through the opening in the base. The dynamite was placed in this bag and the compound plug then screwed into the opening. When the mine was turned back to its proper position, that is, in the position in which it would float in the water, the dynamite would fall down and close around the compound plug. The priming charge consisted of a small amount of guncotton within the priming charge chamber of the compound plug, having the fuses embedded in it. When the fuses were fired, they were supposed to detonate the guncotton, and this, in turn, the dynamite.

In connection with the submarine mine system there is one point of great importance, and that is that the destructive range of mines is much smaller than was popularly supposed. In fact, the usual charge of 100 pounds of dynamite was certain to destroy a well-constructed vessel at a distance of about 20 feet only. In other words, a vessel to be seriously endangered by 100 pounds of dynamite would have to be in contact with or almost in contact with the mine.

In ground mines, and occasionally in the larger floating mines, larger charges of dynamite were used and it was found by experiment that the effective range of the mine was approximately proportiona to the square root of the charge, that is, a 400-pound charge would have about twice the effective range of a 100-pound charge.

The process of the planting of a grand group was about as follows: The grand junction box was placed in a yawl which was rowed or towed to the proper place, being accurately located by transits on shore. When properly located it was anchored and, if it had not already been done, a seven-cored cable was laid from this location to the shore. The next step was to connect the seven-cored cable with the grand junction box. A so-called "Turk's-head" was made at the end of this cable and this was then fastened in the proper clamp of the junction box. The ends of the individual cores of the cable were then separated and exposed, and by means of a telegraph or telephone connection made through the armor of the cable the individual cores were identified with their other ends in the casemate and were tagged.

The next step was to locate the triple junction boxes. These with their loaded cut-out boxes, were placed in other yawls which were rowed into their proper place, the center one being first located from the grand junction box and the others from the center yawl. The distance apart, 300 feet, was determined by a line stretched from one boat to the next, the direction of the line being fixed by a range on shore. After being properly located each boat was held in place by a small anchor.

The next step was to lay a single-conductor cable from each triple junction box to the grand junction box. These cables, whose lengths could be known beforehand, were already fitted with Turk's-heads before being laid and, of course, as soon as they were laid, the Turk's-heads were quickly fastened to the corresponding clamp of the grand junction box in the grand junction box yawl and to the proper clamp of the triple junction box in the triple junction box yawl.

In the meantime there had been placed in the planting boat the loaded mines, cables of the proper length for reaching from the mines to the triple junction boxes (with Turk's-heads already made), anchors, and anchor ropes of proper lengths. While the boat was proceeding to the proper place for planting the mines, the cables and mooring lines were attached to the mines, and the first mine with its anchor, etc., was raised and hung over the side of the vessel preparatory to planting. On arriving at the proper spot, the location of which was estimated from the triple junction box boat, the mine was let go and, of course, dropped to the bottom. The planter at once steamed to the triple junction box boat, paying out the cable as it went, and handing the end of the cable to the man in the triple junction box boat, who at once made the Turk's-head fast to the proper clamp. This man then made a temporary joint between the ends of the two cables, one leading to the mine and the other toward the shore. A preliminary electrical test was made at the casemate and, if all was well, the joint was made permanent. In the same way the other two mines of this triple group were planted. The triple junction box was then closed and lowered to the bottom and the joint pertaining to that triple group was permanently made in the grand junction box. The process was then continued and triple group after triple group was planted. When all the mines were down the cover of the grand junction box was itself put on and this box was then dropped to the bottom.

The above is a very general description of the system as developed by Gen. Abbot. Of course, provision was made for planting mines other than in grand groups and there were a number of refinements in details which it is not necessary to go into here.

Later Developments.

Between the time when Gen. Abbot left Willetts Point in 1886 and the outbreak of the Spanish War a few modifications were made in the system. For instance, the old voltaic firing battery was done away with and a dynamo was substituted in its place; experiments were also made as to the desirability of substituting a storage battery for the voltaic signal battery. The galvanometers upon which Gen. Abbot had relied were superseded by the self-contained ammeters and voltmeters which had been put upon the market, and improvements were made in the circuit closer and cut-out box. These changes, it should be noted, were improvements in detail and changed none of the essentials of the system.

Prior to the Spanish War all the Engineer captains and lieutenants of the Regular Service, with the exception of a few very recent graduates of the Military Academy, had been well instructed in the torpedo system. It had also been customary, for a number of years, to instruct each year about a dozen selected line officers. A few of these line officers belonged to the Infantry and Calvary but most of them to the Artillery. Of course, when the war broke out only a part of these instructed officers were available for torpedo work and many skilled civilian electricians had to be employed.

The greatest shortage, however, was in experienced enlisted men. Previous to the Spanish War three of the four existing Engineer companies had been stationed at Willetts Point. A large proportion of the privates of these companies had been drilled in the mechanical details of mine loading and planting, and there were quite a number of noncommissioned officers who were thoroughly well trained and skilled in all parts of the system. However, immediately after the outbreak of the war it became necessary to send one of these three trained companies to Cuba and another to the Philippines. Another company, or a large part of it, was needed for the Engineer depot, so that there was a great scarcity of Engineer soldiers for torpedo work.

Torpedo material was hastily shipped from the Engineer depot to the various harbors and the mine planting was begun. In this planting many difficulties were experienced. Only one regularly designed mine-planting vessel was in existence and that was needed at New York, so that at all our other harbors tugs or other vessels that were available had to be hired and means had to be improvised for handling the mines.

Much trouble also was experienced from passing merchant vessels whose masters refused to obey the rules set down for navigation during the planting of the mines. At least one boat engaged in mine work was run down and a number of men were drowned.

However, in spite of numerous difficulties, many mines were planted in our different harbors, sufficient to have exercised a strong deterrent moral influence upon the enemy had he approached, even if they had never been able to actually and physically prevent his entrance.

That the mines as planted were harmless to friendly vessels is shown by the fact that not a single accident occurred to a friendly vessel caused by a mine. That the mines are dangerous when exploded is shown by the number of unfortunate and fatal accidents to the detachments that undertook, after the end of the war, to raise and remove the mines which had been planted.

Progress Since the Spanish War.

A few years after the Spanish War the Army was generally reorganized, and since it had been represented to Congress that the submarine mine defense was most closely connected with the gun defense of the harbors, Congress, in its wisdom, by the act of February 2, 1901, transferred the operation and control of the torpedo system from the Corps of Engineers, which had developed it, to the Coast Artillery Corps. In connection with this transfer the engineers were removed from Willetts Point, which had been the home of the Engineer School for over 30 years, and there was organized at the location a new Artillery School of Submarine Mining to take the place of the older Engineer School.

Shortly after this transfer had been made Congress made largely increased appropriations for mine defense, enabling larger quantities of mine materials to be purchased, many mine buildings to be constructed, and several especially designed mine-planting vessels to be built. With the largely increased appropriations which were made available and with the great development in electrical matters which had taken place in commercial life, it was but natural that many changes should be made in the torpedo system. Indeed, it would not have been surprising if the new body of officers to whom the charge of this system had fallen should have practically torn the old system to pieces. They did, indeed, make changes, but considering the circumstances, it is surprising how few these changes were. This can but be considered as a great, though involuntary, tribute to the excellent work that Gen. Abbot had done on the system.

Perhaps the most important change actually made is in the substitution of an alternating current for the heavy direct current for firing the fuses and the substitution of an alternating current transformer for the circuit regulator. Under the new system the current flowing to the mine does not pass through the fuses, but passes instead through the primary coil of a small regulating transformer and then divides, one part going to the circuit closer and the other through a resistance coil to the mine case. This new arrangement has the advantage of doing away with the old circuit regulator, the adjustment of which was somewhat difficult, but it has the disadvantage of placing the fuses in the secondary circuit of the small transformer so that it is impossible afterwards to test them.

The signal current is still a direct current, and of course, while it passes through the primary coil of the transformer, the secondary coil, in which are placed the fuses, is dead. The fixed resistance coil performs now the same function the high resistance coil of the circuit regulator formerly performed. The circuit closer acts in the same way as before and, by the mechanism in the casemate, gives notice that the mine has been struck, and at the same time, if the switch is turned, throws into the mine the firing current. When the firing current, now an alternating current of considerable intensity, is turned on, it passes through the primary coil of the small transformer and induces in the secondary coil a current which passes through and fires the fuses. The voltage of this firing current is sufficient to fire the mine, even though the fixed resistance coil is in series, so that as soon as the firing battery is turned into the mine it is fired whether or not the circuit closer is in operation.

This change to an alternating firing current, although it has the disadvantage of not permitting any subsequent test of the completeness of the circuit including the fuses, is apparently an improvement; but its adoption has been rendered possible only by the recent great development of alternating current apparatus.

Another important change in the system is the doing away with the triple junction box and its cut-out boxes, and the substitution of a 19-cored cable for the 7-cored cable. A grand group therefore consists now of 19 mines instead of 21, each mine having its separate individual core extending all the way back to the casemate. It is therefore possible to test each individual mine instead of each triple group as formerly, and, incidentally, a single mine may now be fired by judgment, whereas before it was necessary to fire three. This improvement was rendered possible by the fact that 19 conductor cables are now manufactured, and these were not obtainable in Gen. Abbot's time.

The change to a grand group of 19 mines having individual cables, instead of seven groups of three mines to the group, has increased by approximately three times the number of cables entering the operating room, and therefore the number of individual operating switches and levers. It became necessary, therefore, to do away with the operating boxes, which under the Abbot system could easily be spread on the shelves around the three sides of a single operating space, and to substitute for them, a series of switchboards arranged around the walls of the operating room.

Each grand group now has its own switchboard, each switchboard being composed of 20 small square panels, arranged four wide by five high. The conductor from each mine leads to its own small panel; the twentieth panel is utilized for switches, signal lamps, etc. The operation of the lever and the magnet on these square panels is on exactly the same principle as in the old operating boxes invented by Gen. Abbot, but a change in the method of mounting on the switchboard has required a change in the mechanical details.

For the old signal battery, composed of voltaic cells, a storage battery is now utilized. This is located in a special separate room. In another room, close to the operating room, there is placed an engine and dynamo for charging the storage battery, as well as the motor generator for furnishing the alternating firing current. The small motor generator is operated by a direct current from the storage battery and gives off at the generator end an alternating current of the proper voltage.

The same selective system of contact or judgment firing is retained, although the tendency has been, so far as drills are concerned, to place more and more reliance upon judgment firing and the tracking of vessels.

TACTICAL USE OF MINES.

Tactically, submarine mines partake of the nature of obstacles, and though they are destructive obstacles, their use is restricted to a large extent by the same conditions that affect the use of other forms of obstacles in land warfare. As obstacles, their principal function is to delay the advance of the enemy, and to delay him in a position where he will be subjected to destructive fire from our artillery on shore. In fact, submarine mines, if used otherwise than in connection with shore batteries, can delay only and can not entirely prevent the entrance of an enemy's vessel. If not protected by gunfire, the mines can and probably will be destroyed by counter mining or their cable connections with the shore will be found by dragging operations and will be destroyed. These dragging operations will probably be conducted by boats too small to operate the circuit closers and too insignificant for mines, by judgment firing, to be wasted on them.

It is essential, therefore, that the mines be located within the field of fire of guns on shore. In the modern system of artillery organization the rapid-fire batteries of any fort, or at least a number of such guns, are usually assigned to the mine commander for the protection of his mine field, so that the use of these guns for the protection of this mine field will not be interfered with by the lack of unity of command, which might occur if these guns were not under the control of the mine commander.

It is, of course, advisable that the mine field should be located so far to the front as to cause the enemy's vessels to halt before they can come close enough to the defenses to make effective use of their rapid fire guns, but at the same time the mines must not be pushed so far to the front as to make their protection by their own rapid fire armament inefficient, or so to make it possible for the enemy under cover of darkness, fogs, or thick weather, to remove, destroy, or paralyze the submarine mine defense.

MORAL EFFECT OF MINES.

One fact strongly brought into prominence in all recent wars is that the efficiency of fixed mines lies largely in their moral effect upon naval commanders. The proper use of any naval vessel is against other naval vessels, and a naval commander is not likely to risk possible instantaneous destruction of his vessel by an unseen mine unless the advantages to be gained are much greater than they ordinarily are. Furthermore, the location and the number of mines which may have been planted, and their condition as to efficiency, will not generally be known to a foreign naval commander who will usually give them credit for being more numerous and better than they are. Indeed, I know one distinguished officer, who, after studying carefully the manner in which the American fleet declined to enter the harbor at Santiago, Cuba, which was supposed to be but really was not defended by effective mines, and the way in which the Japanese stayed out of Port Arthur, stated that in his opinion a most efficient defense could be arranged for almost any harbor by merely pretending to plant mines and then putting up in plain sight of the enemy, as if intended for a warning to our friendly vessels, a large sign marked "Torpedoes."

SUBMARINE MINE BUILDINGS.

When matters connected with the operation of the submarine mine system were transferred to the Coast Artillery, there was left in the hands of the Engineers, the construction of the buildings pertaining to the submarine mine system. These buildings are the mining casemates from which the mines are operated; the conduits connecting the casemates with the shore; the cable terminals on the shore; the cable tanks in which the cable is stored when not in use; the torpedo storehouses in which are kept the mine cases and other material; the loading rooms in which the mines are loaded; the magazines in which the dynamite is stored; the range stations, plotting rooms, and dormitories; the torpedo wharves at which the mine planter is to land and receive the loaded mines; and the tramways connecting the wharves with the cable tanks, storehouses, loading rooms, etc.

Mining Casemates.

The so-called "mining casemates" are in reality not casemates at all; that is, in the sense in which the word "casemate" is ordinarily used in connection with fortifications. They are in reality the operating houses of the mine system and acquired the name "casemate" probably from the fact that many of the older "mining casemates" were made by mere alterations of existing casemates of the old forts, which had become obsolete in so far as locations for mounting guns was concerned.

The mining casement is really the operating house for the mine system and into it are led the cables coming from the mines. In its most modern form a casemate ordinarily consists of several different rooms; an "operating room," in which are located the operating boxes or switchboards, the testing instruments, and other appliances used in the operation of the system; a power room, containing the electric generating plant; a storage battery room containing the storage battery; and a fourth room used as a dormitory or office room.

In the early casemates, as planned by the Board of Engineers, the main consideration seems to have been to provide protection and concealment, and protection seems to have been sought even at the expense of efficiency of operation. As then constructed the casemate consisted of a room about 12 by 18 feet in floor area with a ceiling in the form of a full center arch. No steel beams were allowed in the roof because it was feared that they might affect the delicate galvanometers and other electrical instruments used at that time. The roof and walls of the casemates were of concrete and were very thick, 20 feet on the side toward the enemy and 10 feet on the opposite side. Above and around this concrete was placed a large pile of sand. The entrance was usually through a crooked gallery opening out to the rear, so that by no chance could any projectile enter the casemate. Incidentally, it may be stated that no light could get in and very little air, the only arrangement for ventilation being a crooked ventilator pipe a few inches in diameter and extending from the ceiling to some point on top of the sand fill where its outlet could be concealed.

In the center of the floor of the casemate there was a large manhole covered by a removable trapdoor and connecting with a conduit leading to the shore through which the cables were extended into the casemate. Around the floor, on three sides of the opening of this manhole, there was a line of tables or shelves of suitable height for the operating boxes, etc. The testing appliances, the batteries, and a few other fittings were kept on other shelves placed under the operating tables or around the walls.

In the harbors where there were older fortifications available, the mining casemates were usually built in these older fortifications, utilizing an abandoned casemate from which the gun had been removed, or some other older room. The casemate openings or other voids in the scarp walls were filled with concrete, the thickness of the scarp wall was much increased by adding new concrete, and a great deal of sand was piled around it. Where no good site was available within an older fortification, the casemate was an entirely new structure built preferably in some existing sand dune or other hill.

Although between 1890 and 1898, quite a large number of casemates of the general character described above, were built in the various fortified harbors of this country, but little use was made of these casemates until the Spanish War, and it was then discovered that many of them were so damp that condensation was apt to occur on the electrical instruments with resulting electrical leakage. To do away with the dampness, coal oil stoves and lamps were introduced; but while these lamps were fairly efficient in overcoming the dampness, they soon rendered the air almost unbreathable.

As a result of this experience, the Board of Engineers prepared in 1899 a new design for a casemate which was published in Mimeograph No. 32. In this design the thick concrete wall and the sand protection were omitted from one side and were replaced by a comparatively thin wall with doors and window openings to provide light and air. On the other sides there were to be interior timber walls with an air space between them and the casemate and similarly there was to be an interior ceiling with an air space above. Means were to be provided for artificially heating the air in these air spaces and it was hoped by these means to prevent the trouble due to dampness.

It was soon found out, however, that the casemate proposed was too small, especially when the storage battery had to be provided instead of the older galvanic battery.

In 1903, therefore, the Board of Engineers presented a new plan published as the second supplement to mimeograph No. 32. In this new plan, the dimensions of all the rooms and the number of rooms were increased and sleeping accommodations for the operating detachment were provided. The casemate was now to consist essentially of a frame building constructed in the vacant space in a large concrete mass, the building being completely surrounded on all sides by an air space. The roof was to be made waterproof so that any dripping or seepage through the concrete might run away. As by this time the delicate galvanometers which had formerly been used for measuring current and voltage had been replaced by the standard self-contained ammeters and voltmeters, no difficulty was to be feared from the use of iron in the concrete, so the ceiling was shown as built of reinforced concrete. On one side, that is, the side to the rear, the exterior concrete wall was to consist essentially of concrete columns to be pierced for doors and windows opposite the similar openings of the interior frame building.

In the mimeograph instructions, it was stated that when the casemate could be built in a location where it would be entirely protected from hostile fire, the mass of concrete even might be omitted so that the only thing which would have to be constructed was a structure essentially similar to the frame building itself.

The first casemate of this last type which was built was at Fort Monroe, Va. The casemate was located on the parade level of one of the bastions of the old fort, and being surrounded on all sides, except the rear, by the masonry ramparts of the old fort, this position was supposed to provide sufficient protection.

The use of timber as the material for the casemate was intended to reduce condensation, but of course it made the building inflammable. However, as at that time it was customary to build practically all the observation stations of the fire control system of timber, the use of timber for the casemate was in accordance with standard practice. Subsequently, as was noted in the chapter on fire control, it became usual to build range stations not of timber but of cement plaster on metal laths, and a similar change was made at the same time in the construction of mining casemates. Later on, some mining casemates were built of concrete blocks, some of brick, and a number of reinforced concrete.

Since the adoption of the general design of casemates just described, only minor changes have been made. A casemate still consists of four main rooms; at one end, a dormitory for the detachment that in the daytime may be used as an office, next, a large operating room with closets and a toilet, then a dynamo room, and at the other end, a storage battery room.

Formerly, it was customary to have the cables enter a well or manhole under one corner of the operating room, and from this manhole trenches covered with removable sections of floor led around the walls of the room a few feet away from the walls. Over these trenches were placed the operating switchboards.

It was soon found, however, that it was somewhat difficult to handle the cables in these narrow trenches and in the first casemate built at Honolulu, which was designed and constructed by the author, an improvement was made. In this casemate, a cellar some 4 feet deep was constructed under the entire operating room and extended some 3 feet to the front and rear of the operating room forming areaways which were covered by gratings. The cable conduit entered one of these areaways so that the ends of the cable could be pulled into the cellar. The object of the cellar was to simplify the handling of the cables and to provide ventilation. When pulled in, the cables are spread around the floor of the cellar and under their particular operating boards and for the passage of a cable up into the operating room a small hole is bored through the floor, behind the proper operating board.

The Honolulu casemate was constructed with reinforced concrete walls, but for convenience in handling cables and for attaching the wiring, the operating room was finished with a wooden floor and a wooden ceiling. The mining casemates built a few years later in the Canal Zone were of the same general character as that of the Honolulu casemate, being constructed with reinforced concrete walls and having a cellar underneath the operating room.

Most of the casemates constructed by the Engineer Department from 1908, up to and including the year 1917, were of the open type. They were located where they would be well protected by other structures from the direct fire of the enemy and consequently were given no overhead or rear concrete protection.

The experience of the World War, however, has invited attention to the danger from air bombing and to the need of overhead protection for a structure as essential to the defense as a mining casemate. Consequently, reinforced concrete roofs surmounted by earth covers have been added at many of the formerly existing casemates, and future casemate plans will undoubtedly provide for overhead protection.

It will be noticed that the early standard designs for casemates provided an unnecessary amount of protection, with resulting dampness. The designs were gradually changed to the open casemates, without any overhead protection whatsoever. The pendulum is now swinging the other way and the standard design provides complete protection both overhead and on all sides. This tendency must, however, not be allowed to go so far as to permit casemates to be built without sufficient provision for dryness and ventilation.

Cable Conduits and Terminals.

The cable conduits lead from the casemate toward the shore, and if this distance exceeds 200 feet or so, the ease of handling the heavy torpedo cables requires that intermediate manholes be provided. The earliest conduits built were like sewers, large enough for a man to crawl through, and but one conduit was provided for any casemate connection with the shore, all the cables being intended to be hauled through this one. The more modern form of construction however, is to use multiple terra-cotta ducts laid in concrete and covered over with concrete. At intervals, these multiple conduits enter into the side walls of manholes. In general, the torpedo conduit lines are similar to the fire control or power line conduits except that the individual conduits should be somewhat larger.

The cable terminal is really a large manhole placed near the sea, on the beach, or preferably behind a sea wall, if there is one. It is provided with rings set in the walls for use in drawing in the heavy cables. In fact, the same character of rings are useful in all the manholes of the torpedo conduit line.

The designs of cable terminals and manholes have become standardized and the standard designs should be studied.

When built behind a sea wall the terminal must, of course, have a connection with the sea by means of a hole cut below low water, and arrangements must be made so that this hole may be stopped up when not in use. When there is no sea wall, this cable terminal is built in the sand beach and at such a level that it will ordinarily be covered by the sand and not be seen. On the side toward the land the multiple duct conduit system enters, and on the side toward the sea openings are made which are temporarily plugged with wooden plugs. When the cables are to be laid, temporary trenches must be dug from this cable conduit into the water. The cables are then laid in these trenches and the ends passed through into the terminal manhole.

Cable Tanks.

Cable tanks are designed for the storage of submarine cables, as experience has shown that this cable keeps best when covered with water. It consists essentially of a tank to be kept full or nearly full of water, the depth of the water being sufficient to slightly more than submerge the standard cable drums. For convenience in handling the heavy drums of cable, a bridge crane with a hoist or block is provided which may be moved back and forth over the cable tank. The ends of this bridge crane are supported by rails placed on lines of columns along the sides of the tank. In order to retard evaporation, a house is usually built over the cable tank.

About 1915, in connection with the pushing of the mine field further to the front, double length torpedo cables were purchased, the drums of which were, therefore, much heavier and larger, both in length and in diameter, than had been proposed theretofore. This rendered it necessary that the cable tanks should be made deeper in order that the larger drums might be completely submerged and that the cranes and hoists should be of greater capacity in order to handle the heavier cables.

The earlier cranes were provided with differential hoists similar to those used for hoisting the projectiles in the shell rooms of emplacements. In order, however, to operate these hoists, it was necessary in raising the drums of cables that the operators should stand right over the cable or very close to it. This required that temporary planks should be placed across the cable tanks whenever it was necessary to lift out a cable and these planks frequently were in the way as the cable rose up above the water.

This trouble was first remedied in the design of the cable tanks for Honolulu, built by the author. In this design one of the side walls of the cable tank was made much thicker so that its top might be used as a walk way. The form of bridge crane provided was such that all three of the motions necessary in the hoisting and operation of this crane could be performed from one end of the bridge by men standing on the top of this wall.

In the design of this cable tank additional improvements were included. The levels of the cable tank and of the tramway leading to it were so regulated that the top of the walls of the cable tank was exactly on the same level as the deck of the cars running on the tramway. The cable tank house was extended at one end so that there was space for one car to come inside; and, on one side of the entering track, a concrete platform large enough to hold two drums of cable was built on the same level as the top of the tank walls. It was therefore of the same height as the decks of the cars. Consequently, from this platform, a cable drum could be rolled to a car or it could be rolled from the car to the platform. In removing a cable from the tank, it would be moved by the crane directly to the car, if the car was there. If the car was not there, the drum would be placed temporarily on the platform, thus releasing the crane, which could bring up a second drum. When the car did come, the cable drum could be rolled from the platform to the car. Similarly the platform would be of service in carrying cable drums to the tank.

On the opposite side of the entrance track from this cable platform was built a small testing house for the periodical testing of the insulation of the cable. In this testing room, in order to reduce vibration, there was provided as a support for the instrument a concrete pier running down into the ground and not touching any portions of the cable tank or the walls.

Torpedo Storehouse, Loading Room, Magazine, etc.

The early designs for these structures were published in mimeograph No. 72 and modifications were published in mimeographs No. 92 and 100 and their various supplements. Still later designs were utilized in the Panama fortifications, the drawings of which should be consulted.

In the Panama fortifications the torpedo storehouse consists of a large concrete two-story building. The lower story contains a very long and wide storeroom, over which there runs a bridge crane which can reach any portion of the storeroom and carry articles to or from cars on the railroad track through the center of the storeroom. The upper story is intended for various purposes, and in order that there may be no columns to interfere with the operation of the bridge crane the floor of the upper story is supported by rods hanging from the trusses of the wide and high roof. Rooms for the storage of special articles are provided at the ends of the storehouse. Outside, on one side of the storehouse, is a wide platform on the same level as the floor of the storehouse and of the platforms of the cars on the track which runs alongside of it.

Many different designs have been used from time to time in building loading rooms and, since the last ones were built, the Artillery Board has suggested still another change in design. So it may be said that the design for loading rooms at the present time is in a condition of flux and subject to modifications.

In most of the plans the loading room has been divided into at least two portions, one for loading the mine cases and the other for loading the compound plugs. The portion of the building intended for loading the mine cases is provided with suitably shaped supports for holding the mine cases in the proper position for loading; that is, upside down. Occasionally arrangements have been made so that the dynamite or the other explosive to be put in the torpedoes may be chuted down into the torpedo from rooms above. Many of the older loading rooms contain small tanks into which the mines may be lowered and tested before they are sent to be planted.

Range Stations and Plotting Rooms.

For the operation of a submarine mining system by judgment firing it is essential that the enemy's vessel be plotted in exactly the same manner as is done in connection with the aiming of the guns and as is described in the chapter on fire control.

The observation stations are of exactly the same character as the observation stations connected with fire control and the plotting rooms likewise are similar. The principal difference is that two primary and two secondary stations are provided for each mine field, and the plotting room is made double size, so that at least two vessels at a time may be followed through the mine fields.

Torpedo Wharves.

Wharves are needed in a submarine mining system for loading the mines on the mine planters. There is no general reason, of course, why almost any wharf could not be used for this purpose, but experience during the Spanish War seemed to show that the operation of planters at the regular wharves provided by the Quartermaster Department for general post use would probably be seriously interfered with at critical times by the movement of troops and the handling of miscellaneous materials. Furthermore, it was considered dangerous to handle loaded mines at the same wharves at which miscellaneous materials were being handled and over which troops were frequently passing. It was therefore thought advisable, when it could be done, to build separate wharves for submarine mining purposes, these wharves, in general, to be used for no other purposes.

As far as the construction of a submarine mine wharf is concerned, no special remarks seem to be necessary, except that it should be noted that the wharf is supposedly built for the use of the mine planters only, and therefore the deck should be built of that height which is best suited to the mine planters, whether or not such height may be convienent for other purposes. Whenever a mine planter is provided with a derrick for handling the mines, and this is generally true, no derrick will be necessary on the wharf; but as it is not improbable that, in some cases, vessels other than the regular planters may be needed, it is well that a submarine mine wharf should have on it at least one derrick.

The standard draft of mine planters for many years has been less than 16 feet, and consequently a depth of 18 feet at low water is all that has been considered necessary at mine wharves. However, there has been a recent tendency to increase the draft of the planters and this, of course, means increased depths of water at the wharves.

Tramways.

Tramways are required for handling loaded or unloaded mines, anchors, cables, and other materials. They should lead from the wharf to the cable tank, torpedo storehouses, and the torpedo loading room. Where the tramway is intended for use with the mine system only, and where no connections with any other railroads is possible or desirable, the tramways used are usually narrow guage. Where, however, a connection can easily be made with a railway system used for other purposes, it is well that the mine tramway should be of the same gauge and that a connection between the two should be made. The cars for use on the torpedo tramway are supplied by the Engineer Department.

PROBABLE FUTURE DEVELOPMENT.

During the World War there has been an enormous increase in the ranges used by naval and seacoast artillery and a resulting probable transfer of the field of any artillery action much farther to the front. Consequently, to be of service in future operations, the mine field must be pushed very much farther to the front than has heretofore been considered necessary. This means much longer cables, greatly increasing the difficulty of laying the cables and the mines; an increased number of joints in the cables, which are always a source of weakness; and an enormous increase in cost. Furthermore, the mine fields are removed so far from the observation stations as to make the the accurate tracking of vessels through them much more difficult. Consequently the comparative usefulness of the Army form of submarine mines would appear to have greatly decreased.

At the same time there has been an enormous development during the war in the use of deep-sea mines, both those which are anchored and those which are allowed to float with the current while automatically maintaining a practically uniform depth from the surface. The planting and control of these drifting mines naturally pertains to the Navy, and the Navy has likewise become so expert as to be able to plant anchored mines in the deep sea many miles away from the coast.

These developments, along with many great improvements in the mobile torpedo, would appear to have relegated the Army type of submarine mine to a comparatively unimportant position. In fact, it would appear as if this type of mine might almost have reached a stage of obsolescence.

CHAPTER XV.

SUMMARY.

In the preceding chapters of this work, the attempt has been made to gather together, for the instruction of student Engineer officers, and for the assistance of such other Engineer officers as may be called upon to take charge of fortification construction, a number of facts which the author has learned from his experience and study of the subject. There have been inserted here hints as to the best methods of doing things, reminders as to certain details which an inexperienced officer might in all probability overlook, and warnings as to things which should be avoided.

The attempt has been made also, by a recital of the history of the development of emplacement design, to show that the accepted standards are based, not upon the mere whims of designing officers, but upon a sort of evolution, based upon experience that has shown which of the many things attempted in the past should be retained and which should be discarded. Furthermore, the attempt has been made, as far as appeared possible, to point out the reasons which appear to underlie the success or failure of the different expedients tried.

It will probably have been noted that the recital of the work actually done seems to cease as of a date several years ago. This is because, for the last few years, there has been more or less stagnation in seacoast fortification matters in this country, due largely to the transfer of the interest and the energy of all concerned to the great war on the other side of the water. Consequently, these notes may be considered as a sort of compilation of past history, made in a well-marked interval between the past and the future.

Up to the present it has not been possible to even roughly predict the effect the experiences of the World War will have upon the future of seacoast fortification construction, for sufficient time has not yet elapsed to permit the lessons taught by the war to be thoroughly considered and digested.

During the war, there were very few instances of combats between coast fortifications and naval vessels. The Allies, as far as we can learn, made no effort to attack, or even to make a demonstration against, the German coast fortifications, and the same is equally true as to attacks or demonstrations by the German Navy against the seacoast fortifications of the British, French, or Belgium coasts.

To be sure, in the early portion of the war, a few German light cruisers, in pursuance of the policy of increasing the frightfulness of war, did make a few raids and bombardments of practically unprotected English coast towns, but the results of such actions were practically nil, and nothing important can be learned from them.

In fact, about the only important instance during the war where naval vessels made a genuine attack against seacoast fortifications was at the mouth of the Dardanelles. Though much general matter has appeared in print concerning these attacks, the writer has been unable to obtain any definite details from which lessons as to fortification construction can be deduced. It is clear, however, that though the fortifications were not strictly modern or up to date, and the naval vessels which attacked them were quite modern, the naval attack was far from successful and, after losing several ships and many men, the British were compelled to cease their efforts without having silenced or materially injured the fortifications, and without having been able to force their way through.

Being unable to destroy the Turkish seacoast fortifications or to push past them, the British later attempted to get around them by land operations, but the naval attack at the Dardanelles had warned the Turks in time, and with the assistance of their German friends they were enabled to throw up land works and to bring sufficient forces together to cause the British efforts at Gallipoli to end in disaster.

During the war the writer of these notes had no actual field experience abroad, events beyond his control having forced him to perform his war service in "The Army of the Potomac." Within the last few weeks or months, however, he has had an opportunity of conversing with a large number of officers of Engineers and other branches of the service who have returned from abroad. Unfortunately, however, the ideas and opinions as to fortification matters received from these different officers are exceedingly diverse, the experience of nearly every officer having been more or less limited, and his ideas having been largely affected by matters which came under his immediate observation.

In summing up for future use the lessons to be learned upon a subject like seacoast fortifications, which were really not actively involved in the recent struggle, considerable care must be taken before actually changing our policies, to get a thorough and comprehensive grasp of all that has happened. Especially must we be careful not to allow our attention to be unduly attracted by what we may call the dramatic incidents of the war.

In connection with artillery, the two remarkable developments of the war were the enormous ranges which were sometimes used in artillery fire and the great advance in the portability of the heavy artillery. So striking were these two developments, that certain officers have returned from abroad imbued with the idea that all guns, whatever their size and function, must be so mounted as to be capable of being fired at extreme ranges and in any direction, and, except where the guns are to be emplaced upon a small island, that they must all be mounted on portable carriages so that they may be carried from one place to another whenever desired.

In some respects, the great increase in the possible range of artillery must necessarily have a great influence upon seacoast fortification design. It makes it necessary that the enemy's vessels must be kept much farther away from the cities or harbors than was formerly considered necessary, and this means the pushing to the front and outward of the seacoast fortifications, and the merging of the subject of what may be called harbor defense, with the general subject of coast frontier defense.

Seacoast fortifications are necessarily merely passive defenses; they can not injure an enemy's vessel unless he voluntarily comes within their reach. They can prevent an enemy's fleet from entering our important harbors, but they can not drive him away from the coast, nor can they prevent him from attempting to land at a minor unprotected port, or on our open coast between defended harbors.

Should an enemy once land on our coast he may, if he is not effectively opposed by our mobile army, proceed to the rear of our seacoast defenses and attack them from that side, and if successful in capturing our seacoast defenses from the rear he may enter the harbor with his fleet and use it as a base for future operations. Or, once landed, he may entirely disregard our seacoast or harbor fortifications and proceed with his army to attack, from the land side, the cities, the navy yards, or the dock yards, for the protection of which the harbor defenses were designed. Or, ignoring the seacoast cities and utilities, he may make a campaign against our interior cities and country.

The first of these possibilities, the landing of the enemy and his then attacking our seacoast defenses from the land side, is one which should of course be prevented, and this can be done only by the construction of defenses on the land side of our seacoast forts. The second possibility, an attack by the enemy upon the cities and utilities protected by seacoast defenses, can only be successfully combatted by the construction around such cities and utilities of defenses on the land side, and by the organization and training of the troops to man these defenses. The third of these possibilities, a land campaign against our interior cities, can be prevented only by the organization and formation of proper land forces.

As was stated in one of the earlier chapters, most of the seacoast defenses existing prior to our Civil War were provided on their land side with regular defenses against land attacks. The forts then built were usually closed works. On their seacoast sides they were designed to combat ships, while on their land sides they were designed so as to be able to resist land attacks, even up to a regular siege. This form of design was rendered possible by the short range of the guns of the day.

Unfortunately, in the batteries and emplacements constructed since the Civil War, provisions for defense on the land side would appear to have been somewhat neglected, probably for the reason that the increased range of artillery had caused land operations to be so extensive that land defenses located close to or immediately in the rear of seacoast batteries would be practically valueless, as an enemy could probably put such batteries out of commission by land guns emplaced at a considerable distance in the rear. Consequently, to be of value the land defenses provided would have to be not defenses of the seacoast batteries themselves but rather land defenses for protecting the entire group of seacoast forts, and not improbably including within the defensive lines cities and other utilities.

Beginning some five or ten years ago, however, the question of the land defense of our seacoast forts, and of the cities protected by them, began to again receive the attention which its importance demands. Boards were appointed for drawing up the defensive lines, for laying out the defensive works, and for gathering together data as to the personnel and material necessary for such land defenses. Much information of this kind has been gathered together and placed where it will be of value.

Later, beginning with the formation of the War Department Board of Review, Gen. Kingman, then the Chief of Engineers, in submitting to the War Department his views as to the adequacy of any seacoast defense project, began the custom of urging that all seacoast defense projects should be accompanied by provisions for adequate mobile armies for the defense on the land side of the areas supposed to be protected on the sea side by the seacoast fortifications under consideration. In many of his reports, he stated to the Board of Review that his assent to the board's project for the seacoast defenses mentioned was based upon the supposition that before this seacoast defense project could be carried into effect, proper provision would have been made for the organization of the mobile land forces necessary for the land defense.

The increase in the range of land artillery, shown during the World War to be possible, has made it necessary to move the defensive lines much farther away from the cities than had heretofore been considered necessary, and the increase in the radius of these land line defense lines has, of course, correspondingly increased their perimeters and multiplied the points at which the enemy may concentrate his attack. In the protection of these defensive lines, heavy mobile artillery, moving upon railroad tracks constructed in advance to positions likewise constructed in advance, will doubtless play an important part. Such guns, before the enemy shall have landed, may doubtless on occasions be quite useful in assisting in repelling a naval attack against our protected harbors, or in keeping the enemy's naval vessels at a distance from our coasts.

However, in the opinion of the author, the importance of having certain armanent portable in no way detracts from the necessity of having, in certain locations in our harbors, large guns permanently emplaced. Seacoast guns, once permanently emplaced, are fixed and will be at their proper places when required. On the other hand, there is always the possibility that should not be overlooked, that a portable gun, either through our own neglect or as a result of the machinations of the enemy, may have been sent elsewhere and will be absent when the need for its use becomes most acute.

It is the opinion of the author that the recent demands, which have been made by some officers who have recently returned from abroad, that all guns hereafter to be installed in seacoast defenses should not only be portable but should be so mounted as to be capable of all around fire and at any degree of elevation, are somewhat overdrawn. They are in violation of the fundamental principle that any fortification design must necessarily be a compromise between a number of conflicting elements, and that perfection in any one detail can, in general, be obtained only at the expense of inefficiency in some other items.

For effective use not only in fixed fortifications but in active land operations as well we must have many guns of many different kinds. We need light rapid fire guns for accompanying the advance of the Infantry in land operations and, to some extent, for combating small boats on the seacoast; we need heavier rapid fire guns for combating on our sea front the secondary armament of naval vessels, and on our land fronts for overcoming the enemy's fortifications and his artillery. Likewise we need heavy guns for combating the heavy guns of the enemy whether on shipboard or on land. No one gun can fulfill all these different functions.

In our seacoast defenses, every seacoast gun should have some one important function to fulfill, and the gun itself, its carriage, and its emplacement should be so designed as to enable it to perform this one important function most efficiently. If, at the same time and without lessening the ability of the gun to perform its proper function, it can be so mounted and emplaced as to make it capable of performing some other less important functions, so much the better; but the arrangements made for the performance of these less important functions should never be permitted to interfere with the efficiency of the gun in the performance of its main function.

The normal function of a seacoast gun is ordinarily to cover with its fire a certain water area, to prevent an enemy's vessel from entering this water area, or to sink the enemy's vessel if it should attempt to come in. Every detail of the carriage, every detail connected with the emplacement, every detail of its fire-control system should be so designed as to enable the gun to bring to bear on this particular water area the most rapid and most efficient fire possible. If, without interfering with the efficiency of this character of fire, for which the gun was especially designed, the gun carriage or the emplacement can be so designed as to permit the gun to fire on certain land areas also, so much the better, but if the attempt to make it possible for the gun to fire on these land areas results in any decrease in the rapidity or accuracy of the fire of this gun at an enemy's vessel in its particular water area, the real value of the gun must have been reduced.

In attempting to make it possible for a seacoast gun to fire toward the land, careful consideration should be given as to whether this fire to the rear, if required, will be long-range fire only, or as to whether it will ever be necessary to fire the gun to the rear at zero elevation or at an angle of depression. Long-range fire on certain land areas can usually be made possible without difficulty, but as was shown in describing the tentative designs of future emplacements, all around fire at zero elevation is not possible with any large gun except by a return to the two-story type of battery, with a resulting resort to mechanical means of handling ammunition and a decrease in the rapidity and reliability of ammunition service. This can but make the gun less efficient in the performance of its main function.

In the opinion of the author, it is far from essential that all guns should hereafter be mounted so as to be capable of firing at the maximum range. That some at least of the guns for the defense of any port should be able to fire at the maximum range is of course essential, but this does not necessarily imply that all guns must be capable of this kind of fire.

Fire at very long ranges where the target is out of sight of the gun, and where position finding is difficult, must necessarily be exceedingly erratic and ineffective. Little material damage will probably be done by such fire and the effect will be moral only. Nevertheless, to keep the enemy's vessels as far away as possible it is essential that some of our guns should be able to fire at such extreme ranges

If the enemy has reason to believe that in the attempt to make this extreme long-range fire possible we have decreased the efficiency of our short-range fire, it is not improbable that he might take the somewhat small risk of rushing through the area covered by our ineffective long-range fire, into the area where he knows that out short-range fire will likewise be ineffective. If, however, he knows that the closer in he gets the more effective our fire will be, he will surely not dare such a risk.

It would appear to have been conclusively shown that our heavy disappearing guns can be loaded and fired more rapidly and efficiently than is possible with any barbette mounts yet designed. To be sure, the range of guns on disappearing carriages is comparatively limited, say to 25,000 yards, but in the opinion of the author it is not improbable that there are a number of locations in our harbors where it is desirable to continue to mount some of our primary guns on disappearing carriages, even though this somewhat restricts their range, for it will result in making the fire of these guns most rapid and efficient at the ranges at which they are capable of firing. Such guns will, of course, be unable to take part in an action at extreme ranges, but when the time does come, if it ever should, when the enemy approaches within the range of these guns they will then be absolutely and thoroughly reliable. Knowing such to be the case, it is quite probable that the enemy will never dare to come within their range.

On a seacoast as extensive as ours it is manifestly impossible that we can defend our entire coast. We may defend our most important harbors and commercial centers, but we can not efficiently protect all our smaller ports or the open seacoast between. Where we do build seacoast defenses they should be strongly built, for weak defenses in some respects are worse than none at all. It is much better that we should have a few well defended harbors than a number of weakly defended ports. In fact, our seacoast fortifications should be well planned, well built, and well armed, not so much with a view of defeating an enemy when he does make an attack as in persuading him not to attack at all.

By defending our most important harbors the enemy will be persuaded not to attack them and will be compelled to land his army, if he feels he can accomplish this successfully, on the open coast or at our smaller ports which lack the wharves, the unloading facilities, and the rail connections usually available only at our larger harbors. The landing of enemy under such circumstances and conditions will necessarily be slowly done, and should give time for the concentration of our mobile land forces.

If our seacoast fortifications at any harbor have been so well designed and built as to have deterred an enemy from attacking them, to have kept him out of a harbor plentifully supplied with landing and dock facilities, and to have forced him to land elsewhere under difficult conditions, and where proper terminal facilities are lacking, they must be considered to have performed most efficiently the main purpose for which they were designed. Nothing more should be expected or desired of them. In fact, a seacoast fortification may be said to have most efficiently performed the function for which it was intended, if it is never called into use at all.

○